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ON KOYL'S PARABOLIC SEMAPHORE.

[Report of the Committee on Science and the Arts.]

[No. 1421.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 4, 1889.

Your committee, appointed to examine the system of signalling devised by Prof. C. Herschel Koyl, for use on railroads and described in the United States letters-patent, No. 384,170, issued June 5, 1888, copy of which is annexed,

Report that: They have examined the semaphore in use on the road and carefully considered the claims made by the inventor and announced in the paper read by him before the FRANKLIN INSTITUTE, at the meeting, Wednesday, November 21, 1888.

The semaphore proposed by Mr. Gregory, in 1841, has been so universally introduced on the leading railroad lines as to require little comment. Professor Koyl's invention

makes the semaphore not only as useful at night as during the day, but it also adds to its utility during the daylight, when the arm can be seen, by reason of its exceeding whiteness from the reflection of the sky, after it has been dropped to the position indicating safety.

Professor Koyl's semaphore arm is made in a curve approximating a parabola, partly covered with glass slightly corrugated to scatter the light.

The parabolic surface is illuminated at night by a lamp placed in the focus of the paraboloid, and the lamp being protected on the plane of the horizontal arm of the semaphore by red glass, shows a strong red band upon the line of the track and for a considerable distance each side of the track, so as to be seen by the men on the engine when approaching the signal on a curve of the road.

The lower part of the lantern used to illuminate being made of clear glass, the arm when dropped to (say) 45°, passes out of the red rays of the light and is made to reflect the light of the lamp and so to present a strong contrast to the red signal of danger visible when the arm is in a horizontal position.

The arm itself being from seven to eleven inches wide, is painted bright red over its surface, with the exception of the medial band of corrugated silver glass, which is four inches wide. The mass of the signal board being red, can be seen during the day in a horizontal position as well as the present semaphore arm, made straight without any reflecting surface. When the arm has fallen to the safety position, the glare from the strip of glass lighted by the sky only, makes the signal more striking during the day than the arm in common use, while at night it presents the great advantage of giving the same red band when the arm is up, and white when it is down, as is visible by day.

(1) Any improvement in the semaphore that will permit it to be seen more clearly during the day is worthy of attention.

The parabolic semaphore can be seen when dropped to an angle of (say) 45°, as a white band of light, more clearly than the fallen arm of the ordinary kind. This is a marked

advantage, as the safety sign is one so strongly emphasized and readily seen.

(2) The semaphore being the standard day signal, it is very desirable that the night signal shall be the same as that used by day.

The parabolic semaphore accomplishes this object.

(3) In making any change in the signals of a railroad, that invention commends itself that can be used without any great change in devices already in use and considered standard.

The parabolic semaphore can be placed on the same irons now used to carry the ordinary semaphore, which is valuable only during daylight; and there is nothing new to be learned by the trainmen.

(4) This signal admits of the adoption of other colors than red and white, for since the reflecting surface gives to the eye whatever colors the lantern used is arranged to furnish, several colors can be expressed by one lantern at different angles of dip.

(5) The band of corrugated glass reflecting the red light of the lantern at night being but four inches wide and being imbedded in the wider surface of the semaphore arm is well protected and less liable to be damaged than is the case with numerous small mirrors at many angles on the ordinary plane arm (which had been tried) and is much more perfect in its action.

Your committee have considered the action of the instrument, both in regard to the extreme distance at which it can be seen and also in regard to the nearness of approach of the observer to the post supporting the arm, and they find it fully meets the requirement, as the distinct color of the mirror ceases to be visible to the engineer only within about fifty feet of the post in passing it and is clearly visible from a much greater distance than the ordinary plane arm. After the red band of reflected light has ceased to be clearly visible, by reasons of the nearness of the observers, the arm is then visible as an object lighted by the lantern. This obtains in a marked degree when in a horizontal position.

They feel that it fully meets the claims made for it by

the inventor as expressed in the paper read before the INSTITUTE, a copy of which is herewith submitted. In consideration of the value of the invention, intended to add to the safety of the travelling public, your committee recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Prof. C. Herschel Koyl for his parabolic semaphore.

[Signed] COLEMAN SELLERS,
Chairman Sub-Committee.
G. MORGAN ELDRIDGE,
BERNARD RAMKE,
LINO F. RONDINELLA.

Adopted, April 3, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

(The following additional facts have been furnished by Professor KOYL.)

The experience of the past nine months has done much to demonstrate the value of the parabolic semaphore in practice and to eliminate the defects of its early construction.

In developing the glass of the reflector, the approximate formula for divergence originally given was found not sufficient for practical purposes, and the glass is now made in accordance with the following formula, which is mathematically accurate. To diverge the light 16° from the direction of the axis requires the surface of the glass to make an angle of 8° with the parabola, and this is attained at blending intervals, for both directions from the axis, and for any intermediate degree of divergence by a wave surface in which, if the wave length be three-eighths inch, the amplitude must be—

$$\tfrac{3}{8} \text{ inch} \times \frac{vers.}{4\ sin.}\ 8° = \text{approximately } .006 \text{ inch};$$

and vertical divergence is gained by a wave surface at right angles to this, so that when one is superposed upon the other, divergence in all directions is the result. The appear-

ance of the glass is shown in *Fig. 1*, and the accuracy of the formula will appear from the following demonstration in

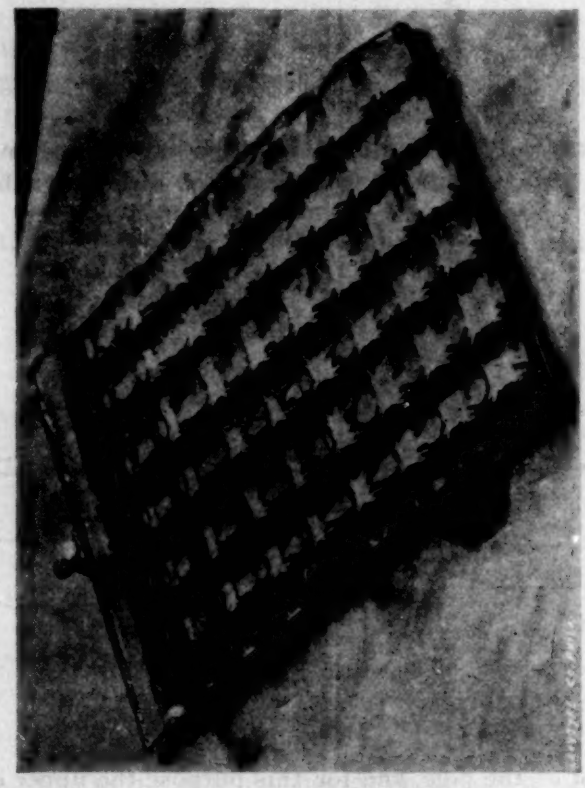


FIG. 1.

which the wave surface is represented (see *Fig. 2*), with the circles from segments of which it is made and in which—

bg = wave length;

bc = ¼ wave length;

ab = amplitude;

the angle $dcb = 8°$;

and the triangles dcb and cob are similar, so that—

$ab = 1 - \cos. 8°$ (or *vers.* 8°);

$$ab : bc = vers.\ 8° \cdot sin.\ 8°, \text{ and}$$

$$ab = bc \left(\frac{vers.\ 8°}{sin.\ 8°}\right)$$

$$= \frac{bg}{4} \times \frac{vers.}{sin.}\ 8°$$

$$= \cdot 006 + \text{inch.}$$

It was further found desirable to have the illumination of the signal uniform from its outer limit of visibility to

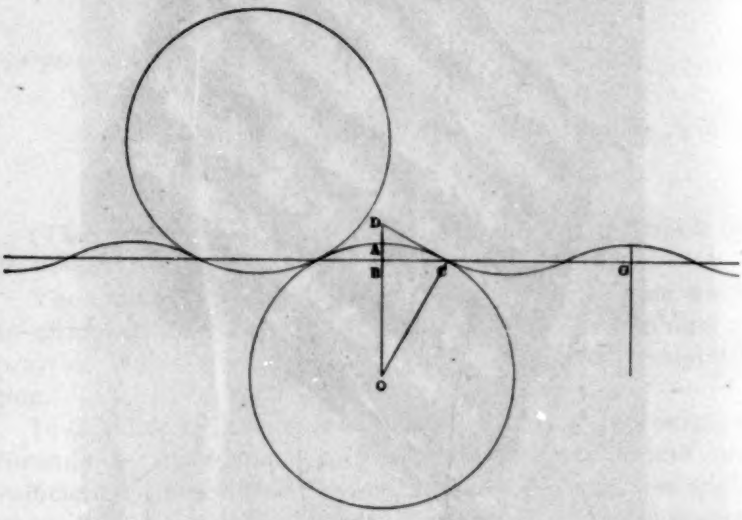


FIG. 2.

the foot of the pole, and for this purpose the upper edge of the glass has been curved, as shown in *Fig. 3*, and the band of light is now visible on the track in immediate proximity to the foot of the pole.

There has never been any question of the value of the signal at night, since, if enginemen are instructed to run by the *position* of the blade, color being used to distinguish "home" from "distant" signals, the trains are relieved from accidents which might follow the breaking of a red or a green glass in the ordinary signal, or the engineman's mistaking a light; but the appearance of the parabolic semaphore by day is not only striking but most important.

It has long been an eyesore to theorists and sticklers for consistency that, though red is used as the danger signal at night, a train must in the daytime regard that same red as a safety signal if only the board is at 45° instead of being horizontal; or, in other words, they argue that as long as color signals are in use, the safety signal by day should be not only at 45°, but *white;* and for the first time in the history of signalling, a semaphore which is red when horizontal is brilliantly white when dropped, the effect being due, of course, to the reflection of the sky light which passes through the vicinity of the focus to the blade, and

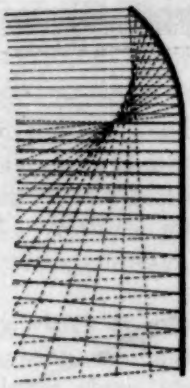


FIG. 3.

further adding to the utility of the signal in that it becomes very conspicuous, and the necessity for a sky background is obviated.

The full-page illustrations show as nearly as may be the appearance of the signal in its "danger" and "safety" positions, by day and by night, and it is seen that, in both cases, for "danger" the signal is horizontal and red, and for "safety" 45° and white. (See *Frontispiece.*)

Fig. 4 shows the semaphore in elevation and plan.

Distant signals are, of course, similarly, green and white, and no movements ever take place in the lamp or in the colored glasses which are part of it.

The parabolic semaphore being both distinct and distinctive, finds its greatest usefulness in the vicinity of cities where lights are numerous, in wooded or hilly country, where the background is dark, and near curves, where it is necessary that the signal should quickly catch the attention of engine or trainmen.

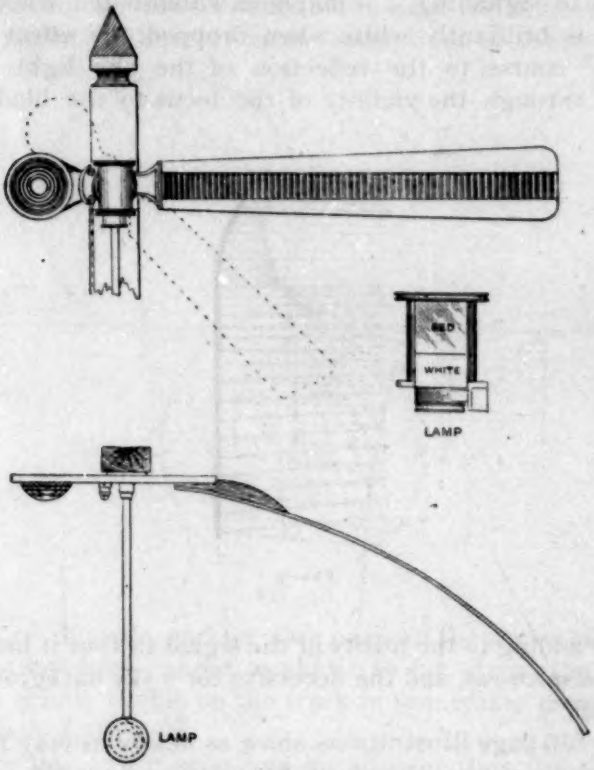


FIG. 4.

The present condition of the glass, which has been in service during the winter, relieves all anxiety on the score of permanency, and snow-storms have not been found seriously to detract from the utility of the signal, because dry snow never lodges on the blade, and wet and frozen snow are themselves excellent reflectors.

OTIS C. WHITE'S ADJUSTABLE EXTENSION MOVEMENT IN BALL-AND-SOCKET JOINTS.

[*Report of the Committee on Science and the Arts.*]

[No. 1416.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 4, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

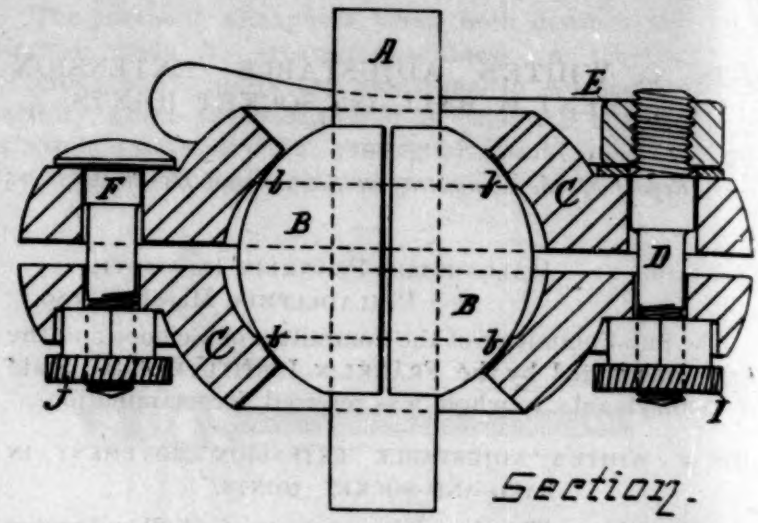
OTIS C. WHITE'S ADJUSTABLE EXTENSION MOVEMENT IN BALL-AND-SOCKET JOINTS,

Report that: This invention consists of a ball-and-socket joint, with the novel and original feature of permitting a longitudinal adjustment of a rod through the axis of the ball, in addition to the ordinary swivelling and rotating movements, and of firmly clamping the rod in any desired position.

The construction by which this is accomplished will be understood by referring to the accompanying tracing (*Fig. 1*).

The ball *B* is made in three separate segments, with sufficient space between them to allow for contraction. The clamping sockets *C C* have each a narrow annular bearing fitting the surface of the ball sufficiently near the equator to produce a powerful wedging action. A conical opening in each socket permits an oscillation of 60° or more. The sockets are held together by two bolts, *D* and *F*, having adjusting nuts, *I* and *J*, on their lower ends, in addition to which the bolt *D* has on its upper end a nut with operating handle *E*. This arrangement permits a delicate adjustment of the amount of compression, which the motion of the lever, by forcing the clamps together, will produce upon the central rod.

In addition to its mechanical functions, this joint possesses the merit of not being dependent upon accurate



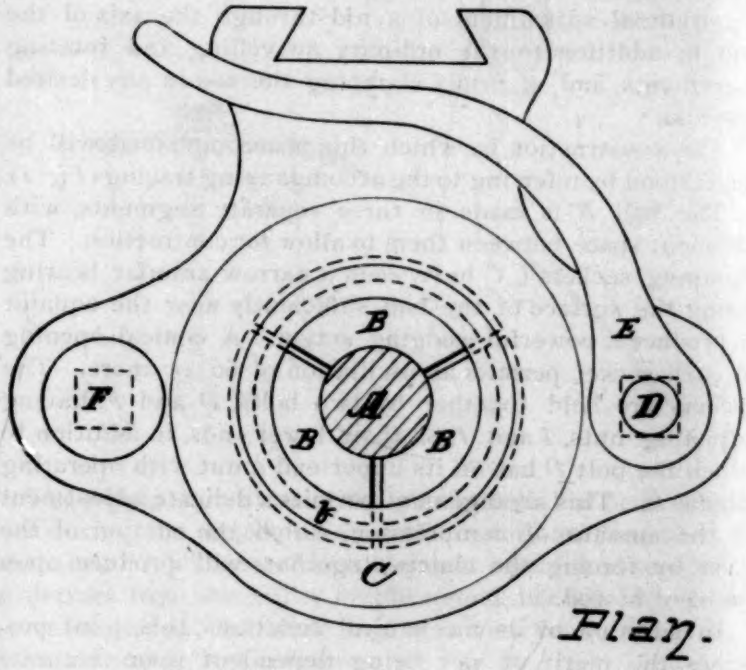


FIG. 1.

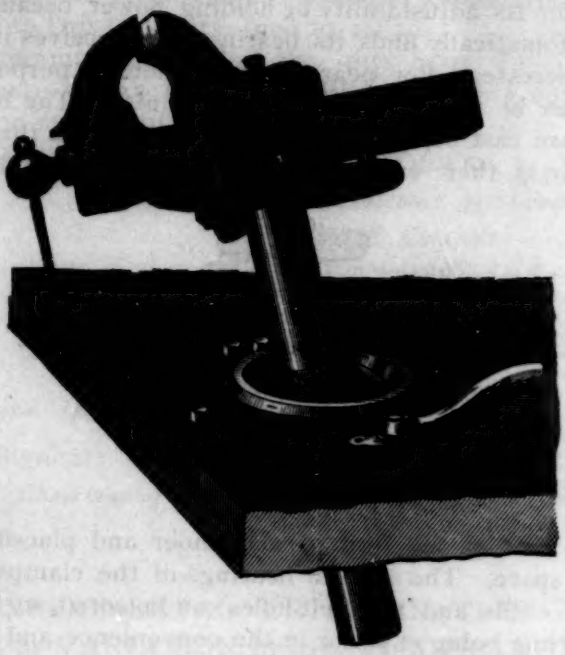


FIG. 2.

FIG. 3.

FIG. 4.

fitting for its adjustability or holding power, because each part automatically finds its bearings and receives its share of the stresses. For nearly all commercial purposes, the joint can be made without any tool finish. The ball segments are cast separate and hollow, bearing on the central rod only at their ends, and are held apart by a flat steel

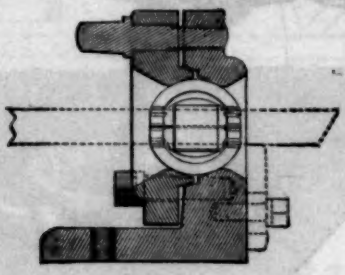


FIG. 5.

spring bent in the form of a cylinder and placed in this hollow space. The annular bearings of the clamps can be cast on chills and the bolt-holes can be cored, so that the joint, while being superior in the convenience and rapidity of its adjustments and the firmness of its grip, and supplying a new and additional movement to the ball joint,

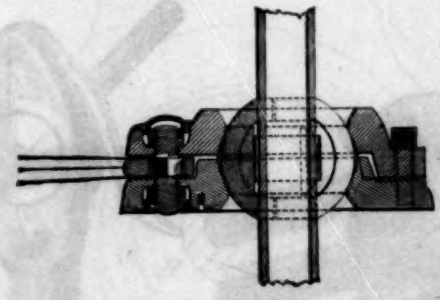


FIG. 6.

can at the same time be more cheaply manufactured than any other device known to your committee which will accomplish the same purposes.

The invention is capable of numerous useful applications, many of which were examined. Its originality is

attested by the broad claims allowed in Patent No. 259,957, granted to Otis C. White, June 20, 1882.

We recommend award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to OTIS C. WHITE for his adjustable extension movement in ball-and-socket joints.

[Signed] WM. H. THORNE,
Chairman Sub-Committee.
THOS. P. CONARD,
D. E. CROSBY,
W. M. MCALLISTER,
LOUIS H. SPELLIER,
C. CHABOT.

Adopted, April 3, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

THE EXPERIMENTAL DETERMINATION OF THE LAW OF VARIATION OF THE ELECTRO-MOTIVE FORCE IN THE ARMATURE OF A WESTINGHOUSE DYNAMO.*

BY LEWIS SEARING AND SAMUEL V. HOFFMAN.

In the mathematical discussion of alternating currents, it has been customary to assume the law of variation of E. M. F. as that of a sinusoid. Previous experiments to determine this law have been made upon machines containing *no* iron in the armature. Recently, Dr. Louis Duncan, of the Johns Hopkins University, has conducted experiments in which he found that this assumption was approximately true with the Siemens machine.

We propose to investigate this law upon a machine *con-*

* Graduation Thesis at Stevens Institute of Technology, Hoboken, N. J., 1888.

taining iron in the armature. To observe the effect produced by varying the conditions, we imposed the following:

(1) Field current, . . 2·15 ampères; load, = 0; speed, = 1,000
(2) " " . . 4·3 " " = 0; " = 1,000
(3) " " . . 4·3 " " = 14; " = 1,000

The machine used was the No. 1 Westinghouse Dynamo in the electrical laboratory of the Stevens Institute; rated at sixty-five horse-power, and requiring a current of seven ampères in the field, when run at its full capacity. The power conveniently available being only a thirty-five horse-power Buckeye engine, accounts for the small figures taken for the conditions.

METHOD.

The method used was suggested by Dr. W. E. Geyer, of the Institute, who had employed it, as early as 1881, on a continuous-current machine. It consists in measuring the difference of potential existing between the brushes for an instant of time, at any angular position of rotation of the armature, by charging a condenser and discharging it through a high resistance galvanometer.

In the practice of this method it was necessary to devise some means of closing, for an instant, the shunt circuit across the brushes to the galvanometer, while the armature was in the desired position of rotation. To effect this, the following apparatus was devised: A ring of brass *R* (*Fig. 1*) was sprung around the turned portion of the bearing nearest the pulley, and to this was secured the piece *A*, to which, at *B*, was hinged the piece *C*, held against *A* by a spring and adjustable outward by the screw *D*. At the upper end of *C* was secured a block of hard rubber *E*, and to this was fastened the plate carrying the steel-wire spring *F*, by which contact was made with the steel piece *G*, highly tempered and ground to an edge in the direction of its length. The steel piece *G* was fastened to the end of the armature furthest from the commutator, with its ground edge parallel to the shaft by means of a V-shaped brass, *H*, and at such a distance from the shaft as to just pass, in its motion with the armature, the contact spring *F*. In holding *H* to the arma-

ture, hard rubber was used as an insulator and electrical connection made between it and one of the commutator rings by a rubber-covered wire running through the air space in the armature. Fastened to the bearing of the

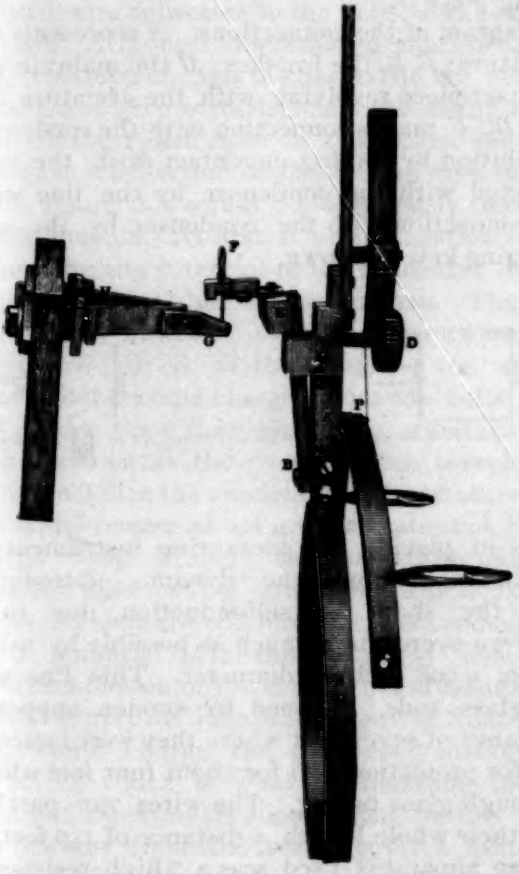


FIG. 1.

machine was a graduated arc of 120°, concentric with the brass ring. A pointer P, on A, served to determine the angular position, in degrees, of the armature at the moment of contact, at which time the E. M. F. existing in the armature was measured.

The contact spring *F*, as finally adopted, consisted of a steel wire 0·034 inches in diameter, bent as shown in *Fig. 6*. One end was inserted in the hole *K*, and secured there by a set screw, and the free end passed through a hole, slightly larger than the wire, at *J*, sufficiently far to make contact with the rotating piece *G*.

Fig. 2. is a diagram of the connections. *A* represents the wire of the armature; B, B_2 the brushes; *M* the main circuit; C_1 the steel contact-piece revolving with the armature and connected with B_1. C_1 makes connection with the condenser, *C*, once per revolution by coming in contact with the steel spring C_2 connected with the condenser by the line wire. B_2 is placed in connection with the condenser by the wire and the discharging key, as shown.

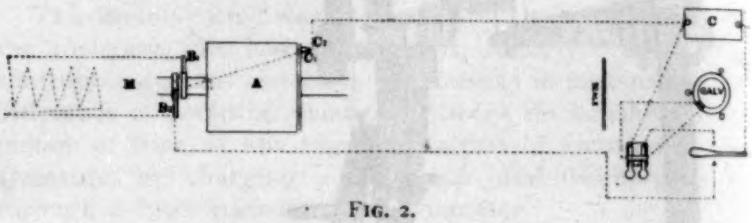


FIG. 2.

The necessity of placing the measuring instruments a considerable distance from the dynamo introduced a difficulty in the shape of self-induction, due to a long line. This we overcame as much as possible by using bare copper wire 0·008 inch in diameter. This line was supported on glass rods, fastened to wooden supports, except for a distance of seven feet where they were fastened to a pine board for protection, and for about four feet where they passed through glass tubing. The wires ran parallel 4·5 inches apart their whole length, a distance of 150 feet.

The measuring apparatus used was a "high resistance Thompson reflecting galvanometer," with its accompaning shunts $\frac{1}{9}$, $\frac{1}{99}$, $\frac{1}{999}$, and two mica condensers of one microfarad capacity (variable, etc.), all of Elliott Bros., London. The scale used with this galvanometer was placed thirty-three inches from the needle and had divisions measuring forty to the inch.

The first difficulty experienced in measuring was that arising from the large static charge induced in the line wires and the metal of the machine by the action of the belts. The first step towards removing this was to connect the body of the machine with the ground, and to furnish pointed wire collectors to the belts, also connected with the ground. Although this removed much of the charge, there still remained enough to charge the 0·1 motive force condenser, and give with the one-ninth shunt a mean but not very constant deflection of twenty-one divisions. As one volt gave a deflection of about three divisions with the one-ninth shunt, this would have seriously interfered with our measurements. At first, it was a question whether we were measuring the potential of the condenser due to the static charge, or that due to the dynamo. The following considerations, however, show that we were really measuring the E. M. F. of the dynamo; for, suppose the condenser had become charged from the belts, etc., to a potential *greater* than that which the armature would furnish, then, as soon as the contact piece completed the circuit which includes the condenser and armature, the condenser would, by reason of its greater potential, immediately discharge itself through the armature until its potential equalled that of the armature, which is the E. M. F. we would measure. If, however, the condenser was charged to a potential *less* than that of the armature, then upon completion of the circuit, the armature, from its being able to supply an infinitely larger current than the belts, etc., would charge the condenser instantly to its own E. M. F., which is what we measure, as before. Moreover, our experiments showed that, in this particular case, the current from the belts required quite a perceptible time to charge this condenser, and give even a measurable charge. An additional fact that no error was introduced by this static charge is evident from the regularity of the readings and the smoothness of the curves.

Two revolution counters were used during the test; the first was an ordinary one, which was held in place by hand while taking speed. This was superseded by a second, the

pinion of which engaged with a worm inserted in the end of the dynamo shaft. This counter was arranged to be thrown in and out at will, and the number of revolutions automatically recorded.

The order of procedure in applying this method was as follows: The dynamo and instruments for measuring potential being about 150 feet apart, in separate rooms, the observers in each room were connected by telephone and bell. The dynamos being started and everything made ready, signals were exchanged to that effect. Then the observer in the dynamo room adjusted the contact apparatus for the first position, numbered 12°, observed the indication of the ammeter in the field circuit, which, if not as desired, was made so by adjusting the resistance in that circuit, rang "go ahead" signal to the observer in the measuring room and upon receiving his answer, threw in the speed counter and noted the time. The observer in the measuring room, immediately upon answering the "go ahead" signal, commenced a series of measurements of E. M. F. of the condenser, by noting the swing of the galvanometer needle, as follows: The charging key was placed in "charge" position and left there a few seconds. One reversing key was then closed and almost simultaneously the condenser was discharged through the galvanometer. As soon as the galvanometer needle came to rest, another charge was measured. These measurements occupied from three to four minutes. Upon the completion of each series of measurements, "go ahead" was signaled to the dynamo room for the contact to be changed to the next position, and the above operations repeated. Speed was usually counted for three minutes, or nearly the whole time of measuring, and therefore the average speed for each series was obtained quite accurately. The variation in the field current during a series was never over 0·2 of a division = 0·04 ampère, hence no correction has been introduced for this. The speed in some cases changed quite perceptibly. To be able to make a correction for this, we determined the law of variation of E. M. F. with the speed in this machine. To do this, we made simultaneous measurements of speed and E. M. F., the latter at posi-

tion of contact apparatus which gave the highest readings, *i. e.*, 34°, a point in the upper part of the curve. This law, as represented by a curve, showed a direct variation, it being almost a straight line. Upon this the corrections for speed were made, the value of the E. M. F. being computed for 1,000 revolutions per minute.

At the beginning and end of each run, which occupied about four hours, any variation of H was observed by noticing the swing of the needle produced by the condenser when charged from a cell of Leclanché battery, kept especially for that purpose. The variations were so slight that they have not been introduced in our corrections.

The corrections to be applied to the readings of the galvanometer were:

(1) A geometrical one, from the fact that the swing of the spot of light measures the *tan* 2 *a*, while the charge is proportional to *sin* ½ *a*.

(2) A correction due to the induction of the shunts.

(3) A correction for the ratio of the shunts.

(4) The resistance of the air to the swing of the needle.

(5) The correction for speed.

The first, second and fourth corrections were obtained in one experiment, by comparing six gravity E. M. F. cells, which were approximately of the same E. M. F. by the condenser method. Then by using one of the shunts employed in the regular work, we noted the swing produced by 1, 2, 3, and so forth cells coupled in series. Knowing the exact comparative values of E. M. F. which the coupled cells ought to give, and by experiment the swing they did give, and taking the latter for ordinates and the former for abscissæ, we obtained a curve for converting the one into the other. This curve approached very closely to a straight line, the ordinates (or galvanometer readings) of which are about four per cent. greater than the abscissæ (or E. M. F. values). This correction was made graphically.

The shunt ratio and induction correction were obtained in one experiment, and amounted to 0·76 of one per cent., which was neglected.

The correction for speed was also made by the graphical method, and afterwards tested by logarithms.

The instrument used for measuring the field current was a portable Thompson galvanometer, and for measuring the main current of the Westinghouse, the Westinghouse ammeter usually accompanying the machine, which was previously calibrated by a continuous current. This instrument could not be relied upon within 0·25 of a division with the current we used.

The main circuit was through a large German-silver rheostat, strung overhead in the dynamo room. When running at night, some of this current was used for lighting.

SPRINGS.

Upon the apparatus for obtaining almost instantaneous connection between the armature and condenser, or, more

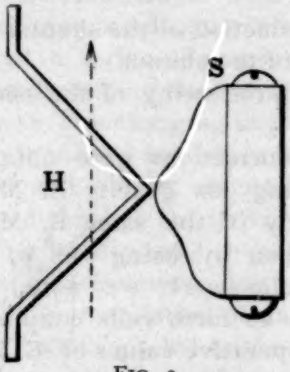


FIG. 3.

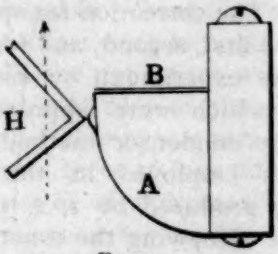


FIG 4.

strictly, upon the pieces which come in such rapid contact, 1,000 per minute, depends the success of this method. Our difficulties and the manner of overcoming them may be of assistance to others. In the first arrangement of these pieces, the end of the brass V, *H* (*Fig. 3*), which was fastened to the revolving armature, came in contact with the spring *F*, made of a strip of spring brass, $\frac{3}{8} \times \frac{1}{64}$-inch, and bent in the form shown in the figure. With this spring the wear was such as to cut through the thin brass in about two hours, and as this wear materially lengthened the arc

of contact, we were compelled to abandon it. We then replaced the brass spring with pieces of clock spring, of several widths and thicknesses, tempered throughout, softened at ends, softened at the middle, and softened throughout; but even the most durable of these did not last over an hour. The majority of them broke at *S*. We then tried the brass spring again, this time capped with steel at its point of contact to prevent wear. This lasted about two hours. We next tried a heavy brass spring ($\frac{1}{2} \times \frac{1}{32}$), tipped with steel, made as shown in *Fig. 4*. The part *A* has a spring outward and is held in check by *B*. The object of restraining the outward tendency of *A* is an important one, and is to shorten its time of vibration to much below 0·001 minute. The next arrangement is shown in *Fig. 5*. The

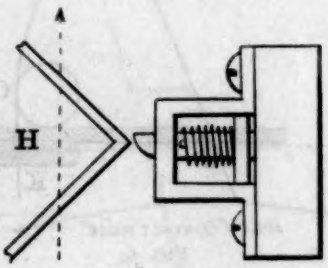


FIG. 5.

piece *H* in passing struck against a steel pin, which action forced it inward against a light spring coiled about it. This arrangement produced such a jarring and such a wear on *H* as to make its use impracticable. From the experience of these springs we learned the causes of failure; one, that the springs used were much too heavy, and another, the most essential, that the path of the contact point of *H* was parallel to the surface of the part with which it came in contact, producing a direct blow and slide; whereas the path of each should have been tangent to each other, in order that the parts would approach and immediately recede, thus allowing, by means of the adjusting screw, a contact of almost any delicacy. The longer the arc of contact, the result of construction or wear of parts, the greater the variation between readings taken at any point in the

curve. To prevent this, we arranged to have a knife-edge of hardened steel strike the end of a very light steel-wire spring (·034 inch diameter), as described in a former part of this paper.

The first spring used was bent as in *Fig. 6*, but without the coil at *G*, and broke at the point where it was clamped by the set-screw, before the end of a run. We then coiled it twice at *G*, care being taken in fastening it to have the coils press firmly against the plate, in order that the bending should be confined to the coils. These springs would last about six or seven hours, and were readily and accurately replaceable; so, to avoid the annoyance of breakage, a new spring was used for each run. We then obtained a clear yet light contact that was in every way desirable.

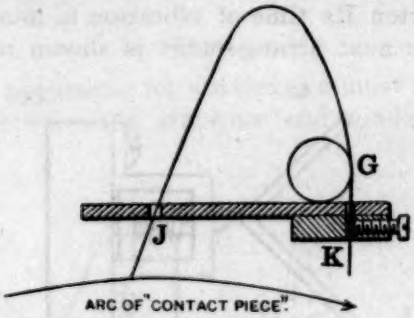


FIG. 6.

TABLES.

Tables giving the results of the observations were made, a very short abstract of one being here given to illustrate the form.

The first column on the left gives the position, in degrees, of the arc previously mentioned, at which contact was made. This arc, of which the 0° was arbitrarily assumed, was for the purpose of measuring the abscissæ of the curve, and for determining the position of the armature coils in reference to the field magnets for any E. M. F. in the armature coils. The 0 of the *curve* happened to come between position 14° and 15°, and as the readings about these points were uncertain, we started measuring at a point a trifle before the curve cut the axis.

Column 2 gives the shunts used, and as the condenser was generally the same value throughout a run, its value has been placed at the head of the tables and any change noted in the column of "Remarks."

Column 3 contains the actual readings (right and left) made on the galvanometer scale.

Column 4 is the mean of these readings reduced to a value which would be given by the $\frac{1}{99}$ shunt.

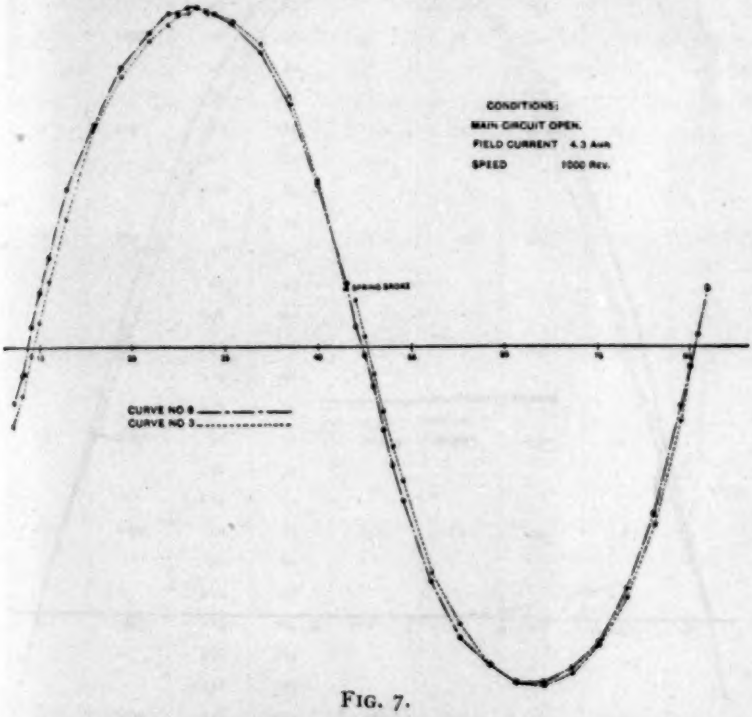


FIG. 7.

Column 5 contains the readings with all corrections applied, but reduced, as in column 4.

The remaining columns explain themselves.

These curves were taken under the same conditions, in pairs, so as to verify each other, as in *Fig. 7*, and then the mean readings of the two plotted, as in *Fig. 8*. In order to show how closely they follow the "sine law," a sinusoid has then been traced over them and is the inner line, *Fig. 8*, and

as will be seen on inspection, the agreement is quite close; the most marked difference occurs between the positions 16° and 27°, 36° and 48°, and on the reverse curve, positions 52°–63°, 72°–84°, where there is a sort of bulging out in the direction of rotation of the armature. The cause of this is not known, so far as we are informed.

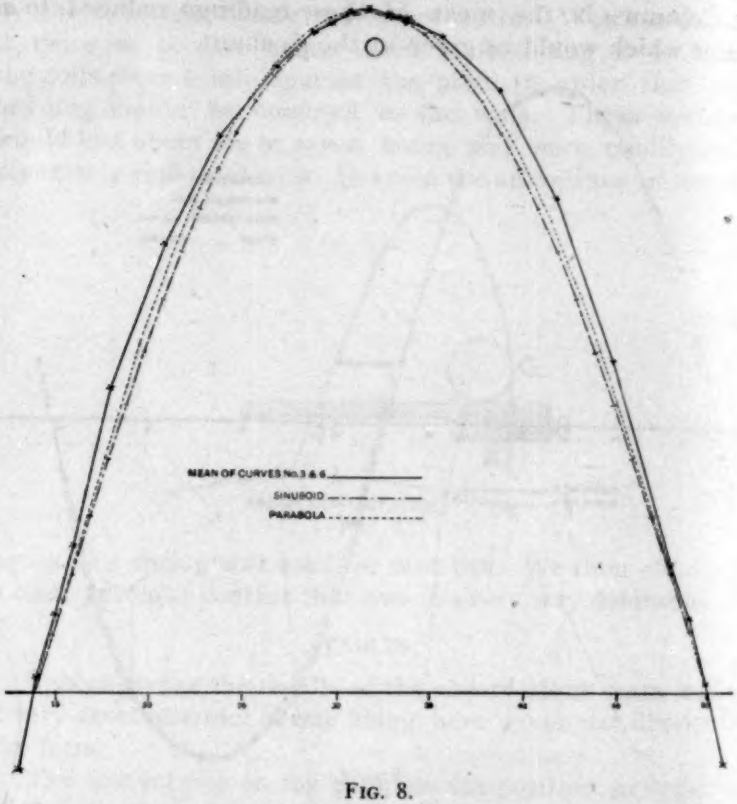


FIG. 8.

The direction of rotation of the armature is shown by the arrows.

Fig. 8 shows only one branch of the curve. Over this curve has also been traced a parabola, the focus being at the point O. While the curve cannot be said to follow the "parabola law," as it has two branches and the parabola only one, still it will be noticed that the parabola is much nearer the true curve, for one branch only, than the sinusoid.

CURVE No. 1.

Conditions.—Main circuit consisted of about 36 ohms German-silver wire in parallel with eleven lamps of 16 candle-power in series. Field current, 4·3 ampères.

1. Microfarad Condenser. May 8, 1888.

Pos.	Shunt.	Readings. Left.	Readings. Right.	Mean Reading.	Corrected Mean Reading.	Speed.	Current in Main Circuit.	Remarks.
		−46	43					
12°	1–99	46	43	45·	47·	952	14·0	. . . . .
		48	44					
		−285	263					
13°	1–9	283	261	27·2	27·	955	14·0	. . . . .
		286	262					
		−68	65					
14°	1–9	63	54	5·7	5·8	965	14·0	. . . . .
		48	52					
		61	45					
		+98	100					
15°	1–9	95	101	10·08	10·	956	14·0	. . . . .
		109	102					
		+33	30					
16°	1–99	32	31	31·5	33·	950	14·0	. . . . .
		32	31					
		+64	63					
18°	1–99	68	63	64·3	67·	947	13·7	. . . . .
		66	62					
		+114	108					
21°	1–99	115	109	112·	114·	957	13·7	. . . . .
		116	109					
		+151	138					
24°	1–99	148	140	144·5	149·	951	13·7	. . . . .
		150	140					
		+173	160					
27°	1–99	173	164	168·	172·	949	13·7	. . . . .
		175	163					
		+182	167					.
29°	1–99	181	167	174·1	178·	952	14·0	. . . . .
		181	167					

CURVE No. 1.

Pos.	Shunt.	Readings. Left.	Readings. Right.	Mean Reading.	Corrected Mean Reading.	Speed.	Current in Main Circuit.	REMARKS.
54°	1-99	— 75 76 73	70 71 70	72·5	75·	943	13·9	. . . . .
57°	1-99	— 118 119 119	112 113 111	115·3	119·	946	13·9	. . . . .
60°	1-99	— 150 150 150	141 141 141	145·5	147·	936	13·7	. . . . .
63°	1-99	— 174 171 173	161 163 161	167·1	173·	943	13·9	. . . . .
66°	1-99	— 186 184 184	173 181 181	181·5	187·	942	13·9	. . . . .
69°	1-99	— 190 189 190	175 175 175	182·3	188·	938	13·9	. . . . .
72°	1-99	— 184 186 187	172 173 173	179·2	185·	943	13·9	. . . . .
75°	1-99	— 172 172 172	160 160 161	166·1	171·	943	13·9	. . . . .
78°	1-99	— 147 145 144	136 136 135	140·5	145·	949	14·0	. . . . .
81°	1-99	— 98 103 99	97 95 94	97·7	101·	950	14·0	. . . . .
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . . . .
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . . . .
84°	1-99	— 42 44 45	44 43 45	43·8	46·	943	14·0	. . . . .
85°	1-9	— 193 193 186	182 180 184	18·63	19·	943	14·0	. . . . .
86°	1-9 0	+ 7·0 + 9·8	. . . . .	·84	·85	958	14·1	E. M. F. readings very variable.
87°	1-9	+ 235 238 210	214 203 190	21·5	22·	943	14·0	. . . . .

HEATING AND VENTILATION OF PUBLIC BUILDINGS.

By Thomas Elkinton.

In the sixth month number of *The Student*, for 1888, was published an article furnished by me at the request of the editor on the subject of "Ventilation," which treated of a few general principles, and of their applicability to dwellings and other buildings, but the scope of the article did not cover more than the commencement of the subject and did not touch upon any of the methods of accomplishing the desired results.

It is a hopeful sign that the public mind is becoming more and more awake to our needs for improved ventilation in large buildings and to realize that while good progress has been made in civil and mechanical engineering, and much attention paid to architecture and substantial building, sanitary engineering and hygiene have been greatly neglected.

Probably one reason for so little progress having been made in these matters is that in the first place the problems are really very difficult ones to deal with, and the ability to deal with them, though obtained partially by study, comes better by more extended and continued observation than is usually given to it, and very unfortunately, ventilation is a subject on which one is tempted to enjoy a confidence inversely as the extent of his knowledge.

With every one thus the director of his own ventilation and his own plans of hygiene, the demand for persons skilled in the profession in these lines has heretofore been very limited, and buildings for generations have been erected with but little provision for a proper air supply for the inmates; and, as a result, the hygienic condition of most of our buildings is far from creditable to an age pretending to civilization and refinement.

Professor Morse, in his *Japanese Homes and their Surroundings*, remarks that a Japanese "would look upon the usual

public gatherings of our people in lecture-halls, school-rooms and other closed apartments * * * as filthy in the extreme." A judgment which the sooner we realize as correct, and the sooner we aim to render untrue, the better for our general health.

As a rule, the offices in which business men spend most of their time become very foul when the weather requires the windows closed; lecture-rooms generally dismiss their audiences in profuse perspiration, and with lungs which have been bathed with the exhalations of many others; and court-rooms and other places of mixed assemblages hold their occupants and attenders for hours in an atmosphere totally unfit for the health of human beings.

These evils being apparent to the most careless observer, and the necessity for improvement partially acknowledged, the next step is the arousing of public interest to the point of declining to rest short of their removal, and to publish methods by which this may be effected.

As above intimated, the first idea to dismiss, is that properly heating and ventilating a large building, as it should be done, is an easy thing to accomplish, and that while we must not stop short of good results, far in advance of what we have as an average been heretofore contented with, we must realize that perfection is a matter of the future, or at least not of the immediate present.

He who deals with currents of air finds, in its elasticity, laws of motion, temperature and moisture, features which baffle him at unexpected turns, however long his experience and close his observation.

Experience, however, does teach, and knowledge is power, even when dealing with air, and although we may be but upon the threshold of what we may in the future accomplish in heating and ventilating our buildings, we have already enough at command, if we will but use it, to vastly increase our physical comfort and welfare, and may leave to our successors to improve as they can upon our methods and appliances.

Another matter to be dismissed from the public mind is the idea that heating and ventilation are to be satisfactorily

obtained without paying a reasonable price for both plant and maintenance.

Too often is it the case that the expenditure of a few thousand dollars for matters of architectural effect or decoration of interiors is borne with greater equanimity than the expenditure of an equal amount for the more useful appliances of a good and healthful air supply for the inmates.

It is not well to build and finish offensive to the eye, but much better to fail to please the eye than to fail of an adequate food for the lungs, and to entail consequent impoverishment of the blood.

To heat without ventilation may be done at comparatively little cost, but as the ventilation for large and continuous occupancy means the changing of the volume of air at short intervals, the cost will be greater, though not in proportion to the number of changes and not in proportion to the increased benefit.

Fifty years ago, buildings were heated by stoves and had no provision for change of air beyond the leakage of the doors and windows and the flow of air through the walls. It may be remarked in passing, that a room heated by stoves will remain for a short time surprisingly pure in its condition, because of the rapid transfer of the lower strata to the upper by the currents induced by the hot surfaces of the stoves, but when the volume of the room becomes uniformly bad, as it quickly does, the condition cannot be described in terms of refinement.

No public buildings now are constructed without some recognition of the importance of ventilation, but, as a rule, the recognition is scarcely more than in appearance, providing, as they do, only partial outlets for foul air with scarcely any opportunity for the inflow of pure air, the fact being seemingly constantly overlooked, that while the provisions for the passage of foul air are well enough in themselves, they are of little account without provision for the inflow of pure air.

It is true, windows and doors afford inlets for air, but as the choice between pneumonias and neuralgias and the evils of foul air are not worth discussing, all such sources

of air supply is to be dismissed from a discussion of apparatus adapted to American winters.

Much difference of sentiment exists as to the proper temperature for rooms best promotive of the comfort and health of the occupants, and the ideas of different nations present curious phases.

Curtis tells us that the Chilians, with a climate similar to that of Washington, think that fires in a house are unhealthful, and wear their heavy wraps indoors as well as out, and although coal is cheap and wood abundant, sit in their houses with noses blue and teeth chattering, and at fashionable gatherings women appear in evening dress, with the thermometer between 40° and 50°. He also states that the mortality from lung and throat complaints is reported to be immense.

The Englishman, too, sits in his large parlor with a small grate, and considers himself comfortable with the thermometer in the fifties.

The proper temperature for every individual is probably that at which he is most comfortable, and this will vary with the physical condition and manner of dressing; one who dresses very warmly needs but little for wraps, and will be oppressed with a temperature agreeable to one who makes more difference between indoor and outdoor wear.

As "comfortable" points, however, are not in use on the thermometer scales, we must express ourselves by the degrees marked upon them, and in practice an average amount of comfort may be secured in our latitude by about 65° for audience chambers, where the occupants sit with their wraps, 69° to 70° for schools, and 1° or 2° higher for parlors, with elderly people in the family.

Heating a building is generally attended to so far as providing against its being too cold, but the regulation of the temperature to provide against overheating and for the supply of a proper volume of pure air, are points which are very seldom secured.

Omitting for the moment the regulation of the temperature and considering the volume, and without citing all the authorities as to what constitutes a proper air supply *per*

capita, it may be briefly stated that they vary from ten cubic feet to sixty feet per minute, the lower estimate, however, being based upon the theory of each one in an audience receiving at each inhalation a supply of pure air, and discharging it where it cannot be again used, a condition only possible out of doors in a stiff breeze.

Sixty cubic feet of air *per capita*, per minute, for an audience, school-room, or class-room, with much more for the sick-room and the hospital, will, it is to be hoped, at an early day be acknowledged as the requirement for good ventilation, but in the present stage of education in these matters it is probably, as a matter of expediency, better not to state the scientific requirement, but, in order not to defeat the rising tide of healthful sentiment, name forty cubic feet per minute *per capita* as a satisfying quantity for the time.

Forty cubic feet *per capita* per minute means for a class-room with thirty, 1,200 feet per minute; for a parlor of fifty visitors, 2,000; for a school-room of 100, 4,000; for a lecture or court-room of 500, 20,000; and for an audience of 1,000, 40,000 cubic feet; and lastly, for the larger audience of 2,500, 100,000 cubic feet of air per minute, as the requisite air supplies for a moderate estimate of the human needs when thus assembled.

How many of the buildings of the day are thus furnished with an air supply like this, or anywhere approximating it.

Doubtless, these figures are startling to such as have not considered them, but they are not unreasonable, even if we have lived for many years with but one-fourth or less of the supply, when we have been at lectures and elsewhere in large audiences and crowded rooms.

Suppose each of our heads were encased for a minute in an air-tight box less than three and one-half feet dimension for each side, or forty cubic feet capacity, and had taken about a dozen full inspirations and expirations of our lungs, would we not deem it proper to have a fresh box at the expiration of that minute, especially if, instead of having the air-tight box exclusively for our own use, we were sharing our exhalations with a neighbor, and in turn were partaking of the exhalations of his lungs?

An audience room for 1,000 seats on floor and galleries would be about sixty feet wide, eighty feet long and twenty-five high, and contain 120,000 cubic feet, and the introduction of 40,000 cubic feet per minute would change the entire volume once in three minutes, or twenty times per hour, a change which it is to be hoped the future will deem little enough, but is immensely in advance of the average present usage, which probably often does not change more than three or four times per hour, if even that frequently. For reasons which I cannot explain, unless it be that for the same percentage of vitiation, the unpleasant odor developed is less when the air is quickly changed than when it is slowly changed, I am inclined to the view that there will, for large, crowded rooms, be the same apparent sweetness, on a less inflow *per capita*, than in a smaller room with fewer in it. Thus in a class-room of thirty, with at least twenty feet *per capita* of inflow, the room has seemed more foul to me than a lecture-room crowded by an audience of 500 persons did with the same supply *per capita*, or 10,000 cubic feet per minute, and I am satisfied that a sitting-room with three or four occupants and closed doors will not remain pleasant short of sixty cubic feet per minute air supply, and that a class-room requires forty feet *per capita*, and that a larger audience will be equally comfortable with a little less; but without explaining these differences, I would have the air supply whenever possible up to these requirements.

The degree of temperature and the volume of air per minute to be maintained having been fixed upon for our needs, further details remain to be considered.

There are probably but a few buildings in existence in this country in which, on continued occupancy by large assemblies, the temperature does not, in a short space of time, rise to an uncomfortable degree, even, it may be, so much as 20° in the course of an evening or single session, and be maintained at these points, although the closing of registers and radiator valves has discontinued the source of applied heat. Apart from the heat of the lamps and gas lights, the main source of increased heat comes from the

audience, each one of whom is a human stove of 98° temperature, radiating what with a few in a room is scarcely perceptible, but with many produces a great increase, and hence it is that while for the warming of a room in cold weather previous to its occupancy the incoming air must be at a comparatively high temperature, it must be greatly reduced after the human stoves have occupied the room and their wraps and outside clothing, cooled by the weather before reaching the room, have become of the same temperature as the room.

As we are considering only the problems of cold weather, we dismiss as dangerous and barbarous the relief of overheated rooms by the opening of doors and windows to the outside air, and can allow of no arrangement but that which supplies the place of the outgoing impure air with that which is fresh and has been properly warmed.

Considering next the principles to govern the arrangements for the exit of foul air from occupied apartments, there has been more or less controversy as to whether ventilation should be from top or bottom, with the probably now well-accepted result that both are correct, according to circumstances.

In a room with few occupants, the greater part of the air exhaled from the lungs cools and falls to the floor, being also increased in specific gravity by the impurities added to it in the process of breathing, and hence for sitting rooms and chambers, the floor line (not the line above the washboard, as mechanics often insist and too many architects allow) is the proper level for the foul air outlets.

Doubts have been expressed by well-informed men as to the necessity and importance of floor ventilation; but besides the obvious advantage of drawing off the layer of cool air apt to rest upon the floor level, the experiments of the late John M. Whitall, some years ago in the sick wards of the Philadelphia Hospital, by which he found that as he lowered the outlet for foul air by successive steps until he placed them at the floor line, he lowered the sick rate of the ward, demonstrates too conclusively to admit of cavilling

the importance of floor-line ventilation for rooms of small occupancy.

It is true, a portion of the lung exhalations are volatile, and to be found at the top of the room, and for these and the heated gases from lamps and gas-lights a small outlet at the ceiling would be correct; but as open registers at the ceiling would on ordinary occasions be but an outlet for pure air, and a waste of fuel in consequence, it is safe to dispense with them in ordinary sitting-rooms and chambers and trust to the dilution of the upper strata by the warm air rising from the registers to the ceiling and thence falling to the floor and passing out at the floor-line vents.

For parlors, however, where large companies are to be occasionally entertained, it is better to provide ample ceiling ventilation for reasons presently stated, but to be careful to keep them closed ordinarily.

The volatile exhalations which are found at the top of the room become more worthy of attention as the occupancy increases in numbers, and they become perceptible "odor" to visitors from the fresh air, and the question arises, Which is the lesser evil, to provide for their removal at the risk of wasting pure air and fuel and destroying the floor ventilation, or to endure the slight odor, which, if the air supply is at all reasonable, is not serious in itself?

With the usual risks of unskilful handling of registers by careless or indifferent attendants, it is probably better to dispense with the ceiling ventilation, but with skilful and interested caretakers, it would probably be as well in class-rooms and similar rooms to have ceiling registers, with rigid rules for closing them when the rooms are not occupied, taking care also that the ceiling outlets shall at best not exceed in area one-fourth of that at the floor line.

In large and crowded rooms, like lecture and court-rooms and meeting-rooms, the problem again changes. In these cases the air supply will or should be much below that of the temperature of the human stoves, and from these human stoves are continually ascending currents of heated air, carrying with them the exhalations of the lungs, and for such rooms, when sufficient inflow of air is supplied, the

ventilation may safely be at the ceiling; providing, however, a trifling outlet at the floor for circulation purposes when warming the room previous to occupancy, at which time the ceiling outlets should be closed.

Allusion may here be made in passing, to what has doubtless surprised many who have attempted to relieve rooms which were originally constructed devoid of ventilation facilities, by adding ventilation at the top or by the pulling down of windows. They have reasoned that if a room was overheated, the hot air at the top would escape if opportunity was offered, and they reasoned correctly to that extent, but they overlooked the fact that for all the air that escaped there must be an equal volume to take its place; and hence in the room described, the supply would come in just where it went out, or rather a stream of hot air would go out one portion of the opening and a stream of cold air pass in the other part. As air does not heat quickly from itself, a chilling body of cold air, whether from ventilator or window top, falls upon an audience, and as they are previously overheated, the sudden blast is a source of danger to them, and the last state of the audience is worse than before.

An old-fashioned meeting-house in Philadelphia, constructed in the beginning of the century, without ventilator appliances, was altered some thirty or more years ago by the addition of central ventilators in the ceiling, opening with cupola and slat-work through the roof, but they were unavailable in cold weather for reasons above mentioned.

A year or more ago, I tried the experiment of covering one of the ceiling openings with a sheet of metal perforated with small holes not exceeding one-fourth of an inch in diameter, knowing that although the cold air must come through some of the apertures as the heated air passed through other apertures, yet I had a hope that as the incoming currents were finely divided streams, they would, in passing toward the floor, twenty-five feet distant, become so nearly the temperature of the room as to become harmless as to temperature. I was, however, disappointed and the device proved useless; it might have worked if the heated

air had gone out at alternate apertures with those at which the cool air came in, but the probabilities are that the outgoing currents massed at one-half the plate and the incoming at the other, and the latter joining together as they fell, made the operation of the ventilator about the same as if no perforated plate had been used. Very likely, if I had carried alternate tubes to within eight or ten feet of the floor, with the hot-air apertures between the pipes, there might have been better success in the result.

I was lately shown another plan for relieving an oppressive lecture-room of heated air and supplying it with fresh air, but it too was a failure, and I consider all attempts at ventilation and air supply as misspent means and labor, unless they comprise ample facilities for warming or tempering the inflowing air when the weather is cold.

Coming now to the consideration of the methods of heating rooms and buildings, the use of stoves and direct radiators placed in rooms must be discarded, because of their furnishing no air supply to the rooms. Some advantages have been supposed to arise from radiated heat, because affording sensible warmth and admitting of cooler air for breathing, but less stress is now laid upon this than formerly, and it is of no practical account for large audiences.

Openings are sometimes made adjacent to the ordinary direct steam radiators in rooms, but their action is uncertain, as, at times when the wind is unfavorable, the air will pass out through the openings instead of into the rooms, and when the weather is very cold and the wind favorable for the air supply, the portion of steam surface presented to the current of air is inadequate for its warming, and the aperture is closed because the room cannot be kept warm enough on account of the cold current.

Hot-air furnaces are an advance upon stoves, because all the heating done by them is accompanied by a volume of air of greater or less amount, and for years to come, for many private and some public buildings of moderate size, hot-air furnaces will probably be used, and within reasonable limits may answer a fairly satisfactory purpose.

The besetting shortcoming of the day, however, is that the furnaces for buildings, whether private or public, are altogether inadequate in capacity for the work that ought to be done, and the air supply to the furnace and the flues for conducting the air to the rooms are seldom half the size they should be. The consequence is that many buildings cannot be warmed in zero weather by their furnaces, the air supply is never sufficient for the occupants, and as the furnaces are often necessarily forced and without water evaporation, the air is supplied at a high temperature, and the floating particles in the air being burned upon the overheated surfaces, the quality of the air furnished to the living rooms is baked, unpleasant and unwholesome.

It will be urged that larger furnaces will cost more to erect and run, which is true as to first cost, but, within certain limits, not true as to maintenance, because it is quite as expensive to run a small furnace beyond its capacity as it is to run a furnace better proportioned to the work.

In building flues for inflow and outflow, it is not well to build smaller than twelve inches square because of friction, the total area, I think, should equal one-third of a square foot for every 1,000 cubic feet of contents. This will bring controversies between owners and builders; but I have a hope, future owners and builders will be willing to plan their flues first and adapt the balance of the house to them. In large buildings flues eighteen inches square are a good size.

With furnaces or any other method of heating, there should be provision for changing the temperature of separate apartments, without such regulation of the furnace as inconveniences other parts of the house, or the closing of registers and restricting the air supply. This has seldom been attempted. Two cases of private houses are within my knowledge, in which the air was taken at will from the top of the furnace or from the bottom, but the mechanical work was at fault in one case and the flues too small in the other to be wholly successful; but these are matters which experience can quickly cure.

In the case of lecture or other rooms of sufficient size to require one or more furnaces for their especial warming, a

simple device will greatly relieve the overheating. This I accomplished for a meeting-house in Philadelphia by having large openings made in the furnace chambers above the drums and causing the doors to these openings to be worked by the Johnson heating regulating apparatus, which at the same time worked the draught of the furnaces.

Thermostats placed in the meeting-room, being set at a given point, the operation is that when the temperature of the room rises above this point, the draughts of the furnaces are closed, thus reducing the fire, and air is admitted to the furnaces above the drums and passes up into the room only partially heated until the temperature falls to the regulation point, when the cool-air opening is then closed, the air follows the usual course through the heating chamber and the draught is put on the fire.

The foul-air ventilation is at the ceiling, and the apparatus works very well for an appliance made to an ordinary furnace; and all lecture-rooms, heated in the usual way by furnaces, could be greatly improved in this way at a moderate expense, although no furnaces of the old patterns are probably of sufficient capacity and air supply to meet the proper demands of an audience.

The best furnaces for capacity and the best arrangement of heating and ventilating by hot-air furnaces that have as yet come to my knowledge, are the Rutan hot-air furnaces and the Rutan arrangement of flues, furnished and planned by Smead, Wills & Co.

These furnaces are so arranged that the cold air passes at will under the furnace or through it, or partially in each way, and the sizes of the flues are in accordance with a suitable provision for the ventilation of the building.

With the ordinary steam apparatus, indirect heating or placing the radiators at the base of flues is relied on for the purpose of warming the air before it enters the room, and the flow of air through the flues is relied on for the air supply. The current is thus dependent somewhat upon the amount of steam supply to the radiators, and somewhat upon the suction or pull of the foul air or ventilating flues of the building.

This indirect system answers partially well for dwellings and rooms of but few occupants, but is totally inadequate for the wants of class-rooms and rooms of many occupants, as the diminished temperature required when the rooms are full curtails the ascending force where the most air is wanted, and moreover, as the outside temperature approaches the inside requirements, all the systems of natural draughts depending upon the difference in weight of the outside and inside columns of air completely fail of their desired efficiency.

Without dwelling at greater length in illustrating these points, because they are probably obvious to all who of later years have examined the subject and have had experience in contending with the practical solution of heating and ventilating problems, I think it may safely be stated that the time has come for, and the state of sanitary enginering education warrants, the abandoning of all reliance upon natural draughts in the ventilation and air supply of all large buildings or rooms of crowded occupancy of whatever character, private or public, with perhaps occasional exceptions of single rooms opening directly at the top.

This point being reached, there remains only the consideration of its alternative, or forced ventilation.

Forced ventilation may be secured by artificially heating the exhaust flues or shafts, or by exhaust fans, either of which plans will withdraw the foul air from the respective rooms, and thus induce an inflow of pure air to the rooms at the inlet. In some cases, perhaps, this is the most convenient method that can be adopted.

A minus condition to a room, however, will induce currents from all openings, as well as those intended for the air supply; but the leakage from windows and doors of cold air, as well as the quickening of the currents of air cooled by direct contact with the windows and walls, are undesirable.

The minus condition may also, in many cases where the inlets and outlets of the rooms cannot be placed advantageously, result in a direct passage of the pure air to the outlets without distribution through the room, thus making thoroughfares of wholesome atmosphere, but leaving great masses of stagnant air between them.

Ventilation shafts, if of much size, and of a height to be effective, are expensive, and the cost of maintaining the upward current by applied heat is not economical, for the experts tell us that one pound of coal will accomplish twice the work in moving air when expended as power that it will accomplish when expended as heat; and, further, the construction of exhaust shafts is often incompatible with the convenient arrangement for large buildings, excepting by increasing the number of them and largely adding to the cost of construction.

On the other hand, a plenum condition of a room, or that resulting from having the fresh air forced into the rooms, obviates some of the disadvantages of the minus or exhaust system, for the pressure being upon all parts of the room, the cold air is pressed against at all the cracks or leaking places of doors, windows or elsewhere, instead of being encouraged to enter; and, again, an open door from either out-of-doors or a cooler hall or room, is not the means of having rude blasts of shivering air enter the room, disagreeable and dangerous to the inmates. For hospitals and other places, where it is desirable that even small portions of air from a room should not be allowed to pass into other parts of the building, it may be needful to assist the exhaust flues of the rooms by artificial means; but for all ordinary buildings, such as school-houses, lecture-rooms, etc., when properly arranged with vent for each of the rooms, the plenum system will, without doubt, be sufficient and most desirable.

Fans have long been used for producing forced ventilation in buildings and keeping the rooms in the plenum condition, and if properly constructed and proportioned to the work, and properly supplemented with suitable air conduits, are the best means of accomplishing the object in view.

In many large buildings it has been the practice to use a simple wheel of large diameter, with curved flanges or vanes at the circumference displacing large volumes of air, and driving the same into basement corridors or ducts, from which the air passes through the radiators at the base of flues leading to the various rooms of the building.

As a rule, the current of air from wheels of this character forcing the air into large corridors becomes of very little effect at a comparatively short distance from the wheel, partly from the construction of the wheel not being the best for exerting pressure upon the current, partly from the leakage of the duct or corridor, and partly because from the size of the corridor any pressure from outside winds upon exposed apartments would be sufficient to drive back the currents and prevent them from entering the rooms, by cushioning upon the air in the corridor or the supplying duct.

Practically, therefore, the fans thus constructed and arranged are of little value, and in one instance of a large institution within my knowledge, the superintendent ceased to use the fan, and made openings at intervals into the corridor for an air supply, thus returning to the ordinary indirect heating system depending only upon natural draughts. Buildings arranged in this manner would be very much improved by constructing a by-pass or valve work at the base of each flue, by which the air could at will be made to pass through the radiators or around them for the controlling of the temperature in the rooms above, or if a simple regulating apparatus was provided by which the steam supply to the radiators governed the temperature.

The most effective apparatus that has yet been devised for heating and ventilating large buildings of which I have any knowledge, is by the use of an ordinary pressure blower attached to a heating chamber through which it forces the air, and from which the heated air is conducted in air-tight piping of proper proportions, branching off to the various rooms in the building.

For the heating surfaces of the heating chamber the usual steam pipes and coils will answer, but the heating chamber which much more favorably impresses me is one recommended to me by George W. Storer, of 149 North Third Street, Philadelphia, to whom I am indebted for having first called my attention to the efficiency and economy of applying to schools and public buildings the system I am now attempting to describe and recommend—a system

which, it is to be observed, has been generally adopted of late years for warming large industrial establishments, but without the detail needful for use where the buildings are divided into many apartments.

The heater built and used by G. W. Storer consists of two tiers of the ordinary pin radiators, through which the air to be warmed is forced by the blower.

There is an advantage in banking the heating surfaces of a building in one mass, as it puts the control of the steam upon a single valve, if desired, rather than upon a multitude distributed all over the building; for although this does not relieve from care of blast gates and registers at the respective rooms, the care of management of the latter and the cost of repair are much less than for steam valves.

I am also disposed to believe that the loss of heat in carrying the heat to a distance is less than by a ramification of steam pipes all over the building, notwithstanding the superior carrying power of steam, but I apprehend there has not sufficient experience been had to determine this point with certainty.

Less radiating surface for the cubic contents of the building is required when the radiators are concentrated in a chamber arranged as just described than when they are distributed around at the different rooms, and the mains and returns are dispensed with, and the cost of steam fitting much reduced. The total cost of the heating plant of a building by this method, notwithstanding the expense of blower engine and piping for the hot-air ducts, is but little if any more than a plant of the ordinary type of indirect steam heating.

The reason that less heating surface is required for the same work is because a radiator filled with steam under ordinary arrangement can only affect the temperature of the quantity of air which comes in contact with it, but is capable of heating a much larger volume than comes to it when influenced only by natural draughts.

An illustration of the capacities of these pin radiator heaters may be mentioned in the results of experiments in

1887 with a small model in which each tier consisted of three pin radiators, or six in all, the air being forced with a small blower of six-inch outlet.

When the air was forced through the heater under a pressure of four and one-half inches of water, or say with a velocity of over 7,000 feet per minute, the temperature of air was raised from 20° to 163°, or 143°; and with the air pressure of two inches of water, or over 5,000 feet per minute, the temperature was raised to 180°, or 160°. High-pressure steam, or forty pounds to the square inch, was used in both these experiments.

With ten pounds of steam on the heater, and air pressure two inches of water, the temperature of the air delivered was 147°, or 127° of elevation of temperature.

A model of this size is not to be altogether depended upon for calculations of a large plant, but the great heating capacity of the heater properly proportioned cannot fail to be apparent, as also the fact that if two tiers of pin radiators are kept filled with steam it will be impossible for air to get past the radiators at any velocity for convenient use for heating purposes, without being sufficiently warmed.

In a larger heater containing sixteen radiators in each tier, I purposely covered one-half the radiators as well as could conveniently be done in order to test certain points respecting the retardation by friction, thus exposing only eight radiators in each tier to the air supply of sixteen inches in diameter.

With so small a radiating surface and so large a pipe, the temperature was raised 118° with an air pressure of one and one-half inches of water, or a velocity of over 4,000 feet per minute; and 130° with one-half an inch pressure, or velocity of (say) 2,500 feet per minute, or a delivery of (say) 3,000 cubic feet per minute—the outlets not being quite equal in area to the sixteen-inch opening. This experiment must not be taken for a basis of close calculations, because the radiators which were covered over were filled with steam at the same time, and probably contributed something to the temperature, although little or no air passed through them.

Making all allowances, however, and counting the heating surface of the pin radiator at practically eight to eight and one-half square feet, though nominally greater, the heating power is very apparent.

In another series of experiments with the heating apparatus, in which the full capacity, however, was not tested, the water of condensation was weighed.

The aggregate experiments extended over an hour and three-quarters, the temperature was raised 100° on an average, the quantity of air passed through the heater was 472,508 feet, and the condensation was 558½ pounds of water —or reducing this to an hour, the volume of air was 270,000 cubic feet and 319 pounds of water.

Allowing the very low estimate of six pounds of water to one of coal, we have fifty-three pounds of coal as the equivalent of work, or in other words, one-half pound of coal per hour raised 2,700 cubic feet of air 100° in temperature. This is a very fine showing, and six pounds is a very small allowance for the evaporation power of the coal, but there must be a liberal counting on radiation of heat at the boiler before the steam reaches the heating chamber.

Heavy pressures of air are not desirable for ordinary purposes of heating and ventilation, both on account of the strong currents to be handled at the rooms and the apparent loss of heat at the point of delivery from expansion into the room. This, perhaps, is not serious, but care must be taken to have ample capacity of blower and engine for maintaining an air supply in time of storms, when the pressure on exposed sides of a building tends to neutralize the air supply for that part of a building. This difficulty is well known in ordinary methods of heating, and it is owing to the inability of the old-fashioned wheel fans heretofore described, and the modern radial fans known as the wing-fan pattern, to maintain a pressure upon a building, that pressure blowers, such as are constructed for heating and ventilation purposes, are to be preferred, and in fact they are, I think, the only kind of sufficient reliability to be recommended.

Heating plants have long been designed and used essen-

tially upon the plan here recommended, but have not been entirely successful, probably solely through the want of liberality in their proportions, but these are defects which observation will make apparent. It will also require time to bring the system into favor, as it will probably be condemned—as it has been by those, who, upon greater knowledge of its merits, have adopted it.

Future experience will, no doubt, greatly perfect the details; but enough is already known to warrant the venturing upon suggestions.

I recommend taking a uniform pressure of one-quarter of an ounce as the force of the air supply in the main piping, and having the blower capacity per minute at that pressure equal to one-tenth the cubical contents of the building to be heated and ventilated.

In other words, for a building of 500,000 cubic feet contents, the blower should deliver 50,000 feet per minute when running at a speed equivalent to one-quarter ounce pressure, and taking for the equivalent velocity of the air 2,000 feet per minute at the points of exit as the basis of all calculations for the delivery of volume instead of the theoretical velocity of 2,584 feet.

The blower should not be calculated upon this basis at its maximum capacity, but should be capable of being driven at a velocity increasing the air supply to an ounce or more pressure if required.

The basis herein recommended indicates a capacity to change the air in the whole building every ten minutes on a normal speed, which, while not covering all that may be wanted in special rooms, is so far in advance of the prevailing usage as to answer for a beginning at this stage of the science, especially as the surplus power can be held as a reserve.

In practice, the whole of a building is seldom used at once, so that the full capacity will seldom be invoked, and the rooms not in use will, of course, not be drawing upon the air and warmth supply, and hence special rooms may be changed once in five or three minutes if so arranged.

It is a property of air currents from a blower that the

closing off of part of the outlets does not clog the blower, as it really runs the easier, the wheel in the case simply slipping in its own air supply; and as the exhaust steam of the engine is utilized in the heating chamber, the cost of producing the currents and pressure upon the building is very slight.

Great care is needed in the piping for this system, as the engineers and architects accustomed to planning and the mechanics skilled in the workmanship are at present very few; the tendency of the former being to pipe on too small a scale, and the latter to be abrupt in their angles and rough in their work.

As the details must vary with every building, only general principles can be enunciated, and these may require modification in special cases, but the following may be of service as a guide:

The blower being of the capacity indicated, the main pipes leading from it must maintain the full cross-section of the area of the outlet of the blower, until the diverging branches to the various rooms of the building have reduced the demand upon the main, when the main may be reduced in section, care being taken not too reduce too rapidly; small branch pipes of great length are quite undesirable; it is better to so divide the mains as to keep as great a mass of the heated air together as circumstances will allow.

The number of branch pipes to each room will depend on the size and circumstances of the room. One pipe, of eleven inches diameter, discharging at one-fourth ounce pressure would deliver over 1,300 cubic feet per minute, but two pipes of eight inches each would deliver about the same, and by being at different points in the room, secure a better distribution. Unless for small rooms or closets, less than six-inch outlets are not desirable.

The area of the branch pipe or pipes to a room must not be less than one square foot for every 20,000 cubic feet capacity of the room, for changing the air once in ten minutes, and of course must be greater for crowded roams.

As a rule, the blast pipes should not enter directly into the room, but should open into flues or pipes at the rooms

of four times their area, in order to reduce the velocity of the inflow at the room. This refers more particularly to registers or inlets at the sides of the rooms, eight feet from the floor, as with this arrangement I have had no inconvenience whatever from currents, although the smaller pipe within the flue delivered air at the quarter-ounce pressure, or 2,000 feet per minute velocity.

Where this enlarged flue cannot be had for expanding the current, it may, however, do to run some risks of currents. Thus, in a certain lecture-room not originally constructed for this system, I have, through the flues, as I found them, driven three overhead streams of air, delivering not less than 10,000 feet per minute, at a velocity of 2,500 feet per minute, the currents reaching to the opposite wall, fifty feet distant, with but a moderate annoyance from currents in the room; and this annoyance a little change of delivery places will probably remedy.

Round pipes are better than square pipes, a circular pipe one foot diameter delivering air more satisfactorily than a pipe one foot square, with the saving both in mechanical construction and in the material proportional to the relative circumference, or nearly twenty-five per cent.

Corners must always be turned on a perfect curve. I have seen the delivery of pipes almost destroyed by an abrupt turn, although the outlet area was maintained. It follows also that branches must always diverge from mains at an acute angle, and never at 90°, to ensure full delivery.

For large audience rooms liable to be closely packed, the best method of entering the fresh air is through the floor by small orifices, so numerous and of such area that a steady flow passes steadily upwards, without serious draught, to the outlets at the roof or ceiling.

Many audience chambers, however, cannot have the use of the basement or room beneath for the necessary piping or reservoir of air, and in that case, recourse must be had to the sides of the room and the outlets above the heads of the occupants eight or ten feet from the floor, as may seem best, according to the height of the room.

As all machinery is liable to accident, the heating

chamber and blower should be duplicated in cases where a delay in heating would be inconvenient. Thus for a building of 1,000,000 cubic feet capacity, instead of one large wheel of 100,000 cubic feet per minute capacity, two of 50,000, with their respective heating chambers, would be better, placing them contiguous to each other, and arranging so that one could do the work of the other when temporarily necessary. This could readily be done by speeding up above the regular speed, and being satisfied for the time with a little less air supply as a whole.

The fan and heater and piping constitute the main portions of the plant, but other details are of great importance for controlling the temperature of the rooms to be heated without varying the air supply.

In the case of large audience rooms, the simplest plan would be to let one blower ordinarily be in service only for that room, and regulate the temperature by the steam valve of the heating chamber, either with automatic apparatus controlled by a thermostat in the chamber, or, if an apparatus is used which will indicate the temperature of the chamber in the engine-room, the hand of the engineer can, without much care, keep a steady temperature.

This, however, will not be available where several or many rooms are to be heated by the air from the same main pipe.

To meet this case in a building where the basement was not required for other purposes, I devised a simple application of the principle of induction.

In this building the main warm-air pipe starts from the heating chamber with a diameter of fifty-four inches and passes through the central corridor of the basement, branching out to flues on either side and diminishing in diameter to about eighteen inches at the extreme end.

The branch pipes of six, eight and more and less inches enter the flues for the rooms and terminate in the base of these flues with a short pipe above the elbow, the hot-air pipe being furnished with a blast gate worked by a lever in the class-room. The flue is about four times the area of the blast pipe, and at the base on the other side of the corridor

hall has a valve door, which, when open, admits air from the basement around the blast pipe.

The cool-air valve is also worked by a lever in the class-room, and the flue opens into the class-room eight feet from the floor.

The air in the main pipe is intended to be kept at a steady pressure of one-quarter of an ounce and at a temperature according to the weather to afford sufficient heat in any part of the building.

With the blast gates wide open, a flow of warm air enters the room in a volume sufficient to change the volume of the room once in ten minutes, but when the room becomes heated to whatever degree is desired, say 68° or 70°, the hot-air pipe is slightly closed and the cool-air valve is opened.

By this operation the warm air is slightly curtailed, but, as it is still rushing in with considerable force and is surrounded with cooler air from the opening of the cool-air valve at the base of the larger flue, by the principle of the injector or by induction, it carries up a greater volume than has been shut off from the warm-air pipe.

It requires but little care to so adjust the valves as to vary the temperature at will, without diminishing the volume.

This plan, however, would not be available in buildings in which the basement was wanted for occupancy, or where, owing to surrounding buildings or for other reasons, it was not easy to obtain the supply of cool or tempered air at every flue.

These contingencies can be met by doubling the piping system, carrying hot air through one system and tempered air through the other, and entering the branches from both into the flue or directly into the rooms and regulating the inflow by suitable valves.

In this arrangement the heating chambers must be arranged to supply the air at the respective temperatures required.

Flues are the better for being in inside walls, rather than outside, and no fears of good distribution need be enter-

tained, because both inlets and outlets are on the same side of the room.

Where the walls do not admit of good-sized flues, offsets in the room should be endured rather than small flues.

Offsets may be reduced to a minimum by using metal.

Registers should be dispensed with when the inflow is regulated by other valves, and an opening with a neat border and lining will soon be as sightly to the practical eye as registers.

Fans should be run by their own engines, in order that the air delivery may be controlled according to the occupancy of the building, without reference to connections with other machinery.

Moisture should be added to the air after warming. In one case where I failed of sufficient quantity with a large surface of boiling water, I found a steam-jet to answer.

Specially exposed rooms must be borne in mind and specially provided for. Thus in an institution, the newest part of which is warmed on the system described, the temperature was not satisfactory for three rooms very much exposed, the pipes to which were small and carried in outside walls, but all defects were cured by an increase of the air supply.

In conclusion, the object of this is more for the purpose of inciting investigation and much-needed improvements in the ventilation of public buildings, and places where audiences gather and business men spend their time in business hours, than to present a basis for technical contention.

The methods particularly recommended may not be applicable to all existing buildings, though there are but few buildings in and near Philadelphia, however recent their erection, but that greatly need improvements in ventilation. With those who cannot suspend their judgment long enough to understand what is being explained to them without expressing either an adverse opinion or a description of some other system, it is a thankless task to discourse, but those who have worked sufficiently in the practical work of heating and ventilation to realize the real intricacies

of the problems presented, and which vary with every building, everything bearing upon the subject is patiently considered, and with an interest that pertains to seekers for further knowledge.

At the end of ten years, after taking an interest in matters pertaining to ventilation, I felt I was further back than at the beginning, and at the end of twenty years had made but little progress. At the present time, some ten years later, I am only at the point of starting fresh, hoping, however, to give some impetus to the cause, and particularly to incite others to go on to more perfect work.

On the LONGITUDINAL RIVETED JOINTS of STEAM-BOILER SHELLS.*

By John H. Cooper.

The initial statement to the English Lloyd's rules for steam boilers is embodied in the following words: "The strength of circular shells to be calculated from the strength of the longitudinal joints," which assures us that this part of the boiler should be properly proportioned.

To these rules a memorandum is added: "In any case where the strength of the longitudinal joint is satisfactorily shown by experiment to be greater than given by this formula (Lloyd's), the actual strength may be taken in the calculation."

Later on, Lloyd's rules (under the head of "Periodical Surveys," regarding the examination of boilers after they have been several years in service) say: "The safe working pressure is to be determined by their actual condition."

These statements lie in the line of practical efficiency, and point to the necessity of providing material in accordance with the requirement of the load to be carried.

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* Read at the Nineteenth Meeting of the American Society of Mechanical Engineers, and revised by the author for publication in the Journal from advance-sheets of the *Transactions*.

Any one who takes the trouble to collect and compare data on this subject cannot fail to notice the great disparity of rules for determining the working pressure permissible for boilers.

The case is clear by simple reasoning on the data collated, that boilers are held together, it would seem, more by conformity to rule than by the materials of which they are made.

But, of course, the true course to pursue is to give to each member its proper allowance of section, in order that the components of the joint shall have an equal chance under strain according to its resisting power.

The diminished strength of the shell of a boiler by the longitudinal joint is well known, and it becomes good engineering so to proportion its parts as to obtain the greatest strength possible within the limits of practical economy.

When it became necessary to assure themselves confidently of the permanent safety of a structure composed of plates held together by rivets, engineers were not long in finding out that a certain allotment of rivet section to plate section at the joints was necessary, and that these sections were found to be nearly equal in the strongest joints.

The experiments of Fairbairn, conducted in the year 1838, proved that—"the sectional area of the rivets in a joint was nearly equal to the sectional area of the plate through the rivet holes."

Subsequent experiments by Clark on riveted plates for the Britannia and Conway Tubular Bridge fully corroborate the above statement; his conclusion was: "The collective area of the rivets is equal to the sectional area of the plate through the rivet holes."

This relation of the components of the joint in course of time became embodied in the English Board of Trade rules and in Lloyd's rules now in force, regulating the construction of steam boilers. It also forms the basis of the Philadelphia steam-boiler inspection ordinance, first formulated in 1882.

Referring now to those rules only which relate to the proportions of the longitudinal joints of the cylindrical

shells of boilers, we are prepared to say they may be most conveniently presented by the following notation and formulæ:

NOTATION.

A = Percentage of punched plate to the solid plate.
B = Percentage of driven rivet section to the solid plate.
C = The pressure in pounds per square inch, which the boiler is allowed to carry.
a = Area of driven rivet, or rivet hole.
d = Diameter of rivet hole.
n = Number of rows of rivets.
p = Pitch of rivets.
t = Thickness of plates.
R = Radius of boiler shell.
S = Ultimate shearing strength of rivets in pounds, per square inch of section.
T = Ultimate tensile strength of plates in pounds, per square inch of section.
f = Factor of safety.
E = Limit of elasticity in the plates in pounds, per square inch of section.
% = Percentage of joint strength.

The least of A or B should be inserted in the formula C.

All dimensions in inches.

The notation and the formulæ mutually explain each other.

$$A = \frac{p - d}{p} \tag{1}$$

$$B = \frac{a\,n}{p\,t} \tag{2}$$

$$C = \frac{t\,(A \text{ or } B)\,T}{R\,5} \tag{3}$$

These formulæ are intended exclusively for the guidance of the inspector in ascertaining the exact strength of the joints in the boilers which come under his care, and which enable him to determine the working pressure of steam

allowable under the rules. They do not, however, enable the boiler-maker to determine directly that proportion of pitch which he should use with any given plate thickness and rivet diameter, in order to secure the strongest joint and which will also pass the highest inspection.

To secure these results, the following simple formulæ were devised by the writer (early in 1882), in which the notation given above is similarly employed, and which may be thus expressed.

For single riveted joints, when iron plates are secured by iron rivets and when the plate thickness and rivet diameter are given, if it is desired to find a pitch that will secure equality of plate and rivet section, the formula will be:

$$p = \frac{a}{t} + d \qquad (4)$$

This plainly means that the pitch is equal to the area of the rivet hole, divided by the thickness of the plate, and to the result of which the diameter of the rivet hole must be added.

For multiple riveted joints, when iron plates are secured by iron rivets, the same formula is used, with the addition only of n, representing the number of rows of rivets, thus:

$$p = \frac{n\,a}{t} + d \qquad (5)$$

The different resisting power of equal areas of section, as many times found by tests of the shearing stress of the rivets and the tensile stress of the plates, is not taken into account in the make-up of these rules. They are treated in all cases as equals under the strains of continued use. That is to say:

The Philadelphia boiler ordinance and the English rules alike impliedly declare: The shearing strength of the rivets is just equal to the tensional strength of the plates per square inch of area in boilers made of iron plates and iron rivets.

If any one takes exception to this treatment of the two strains, the formulæ permit him to introduce his own figures of difference into their make-up, by which he can get a result

in accordance with his own belief; but of the mathematical base, embodied in the formulæ, we are sure.

For single and multiple riveted joints, when steel plates are secured by iron or steel rivets, the relative resistance of the plates to tension and of the rivets to shear must be inserted in the formula.

First, let us assume, as the rules for inspection have done and do in all cases, that, area for area subjected to stress and acting together, iron plates and iron rivets are equal in resistance.

The "Best" Staffordshire iron boiler plates will stand 48,000 pounds T per square inch of section; but the Board of Trade and Lloyd's limit all best iron plates and rivets alike to 47,000 pounds.

The Philadelphia ordinance will pass iron plates which have shown on test a T of 50,000 pounds per square inch, but will allow no more whatever the plates may show, and will give full credit to a joint in which the driven rivets have equal section to the punched plates.

And yet we well know it to be a matter of fact that the shearing strength is less than the tensile strength of the same material.

Mr. William H. Shock's experiments on American iron gave as a mean for single shear 41,033 pounds per square inch, and 78,030 pounds for double shear, these experiments being made upon iron bolts in a shearing device which did not include the uncertain element of friction by the rough surfaces of the plates when bound closely by the rivets of a riveted joint made in the usual way.

When iron rivets are used with steel plates they are accepted under the rules for just what they are worth under shear and no more. The English rules say: "Iron rivets in steel boilers should have a section of $\frac{1}{8}$ of the plate section." Steel rivets must be calculated from their actual strength to resist shearing; and for these the fraction $\frac{24}{28}$ will express the larger area they must have to the plates with which they are used to make joints, simply because steel plates show an ultimate T of twenty-eight tons, and steel rivets an ultimate S of twenty-three tons per square inch of section.

The old rules published by Fairbairn, and used by him and by many boiler-makers since, are obsolete now, in the light of the later method of proportioning joints and the laws which sanction their use, although he furnished the first material for the base upon which this law has been built.

From an extended list of all iron single joints, proportioned on the principle of equality of sectional areas, the percentage of joint strength to the solid plate will reach to ·64 and in double joints to ·78 and be practically tight under pressures up to, say, 100 pounds of steam per square inch—a material increase over the oft-quoted figures of ·56 and ·70, originated and recommended by Fairbairn.

If we accept the inspection laws referred to, assuming even results of the two strains, then Rules 4 and 5 will find the proper pitches for boiler joints made of iron plates and iron rivets; but in composite boiler shells, the introduction of symbols representing the actual powers of resistance of the components, will be necessary. We will then have for double or multiple joints:

$$p = \frac{n\,a\,S}{t\,T} + d \qquad (6)$$

which can be applied also to an all-iron joint or to joints made of other materials than the usual iron and steel.

In formula 6 may be inserted the elastic limit E of the plates to tension, instead of their ultimate tensile strength, and with this should also be inserted the stress at which the shearing of the rivets begins, together with a factor of safety corresponding to the requirement of these important factors.

If we desire to find the pitch of the rivets, when the rivet diameter and a certain percentage of joint strength are given, we may use the following formula:

$$p = \frac{d \times \%}{(100 - \%)} + d \qquad (7)$$

This does not include the thickness of the plates; it relates only to the proportion existing between the distance

from centre to centre of the rivet holes and the space between the holes.

Other convenient formulæ are readily obtained from A, B and C, by transposition. If, for instance, it is desired to know the S to which the rivets are exposed in any particular case after all the elements have been obtained, the formula will take this shape:

$$S = \frac{C \times R \times f}{t \times B} \qquad (8)$$

and will give the pounds per square inch of cross-section to which the rivets are subjected in the seam by the steam pressure C, which has been obtained by the Ordinance formula.

The *rivet hole* determines the size and measure of the rivet after it is driven, because it is then filled by it; and in making calculations with the aid of these formulæ, the trade sizes of the rivets *must not* be taken.

In punching holes for rivets in boiler plates, it is the usual practice to use punches $\frac{1}{16}$ of an inch greater in diameter than the trade diameter of the rivets, and it is also usual to make the dies which are used with the punches $\frac{1}{32}$ of an inch larger in diameter than the punches to be used with them. The result of this method is to make conical holes in the plates, corresponding to the sizes of punch and die.

If the punched holes are net to the dimensions of the punch and die here given, and if the material of the plate immediately around the hole has not suffered in the act of punching, then the proper size of holes to be used in the formula would be the *mean* diameter of the conical holes so made, instead of $\frac{1}{16}$ of an inch larger than the punch, as they are usually assumed to be.

It is well known, however, that the material of the plates bordering the holes is weakened by the detrusion of the punch; to what distance this reaches from the surface of visible separation of the metal may not be definitely known, and must necessarily be different with different materials and punches, but it is certain to be a small measurable distance into the plate around the hole.

If we take the diameter of the punched holes to be equal to that of the die, we will not be far from the actual state of the case, especially as some of this disturbed metal is removed by the reamer or crushed by the drift-pin.

We are safe in this assumption in so far as the ultimate strength of the joint is concerned, because, as usually happens in rupture, the plates give way, while the rivets rarely fail; and again, the plates suffer loss of substance by wear and waste, while the rivets are preserved against deterioration, and, therefore, the initial strength of the plates ought to be favored.

In view of these facts, the suggestion is here made that when we wish to determine pitches from given plates and rivets, that we use the *greater diameter* of the punched hole, whatever that may be, for the quantity expressed by *a* in all of these formulæ, and that we assume the rivet diameter to be that of the lesser diameter, or reamed-out diameter of the rivet hole.

The result of this apportionment of the material will be effectively to strengthen the plates, which all experience has proven to be necessary; so that while this decision appears to be against reason and the isolated facts of experiment—the resistance to shearing always proving less than that to direct tension in the same material—it must constantly be borne in mind that the strain on the plates and rivets are not *direct* in the ordinary lap-joint as they are used in a boiler, the plates being subjected to some transverse strain while under tension, and the rivets to some tensile strain while under shear.

Strictly speaking, the plate loses what is punched out of it, together with the metal destroyed around the punched hole, and the rivet gains by whatever increased diameter it gets in the process of riveting. They should be estimated upon what they actually are when the joint is made up.

ON LAPACHIC ACID AND ITS DERIVATIVES.

BY E. PATERNO.

[*Communicated by Dr. W. H. Greene, at the stated meeting of the Chemical Section, held June 18, 1889.*]

In the last number of the *American Chemical Journal* (**11**, No. 4, April, 1889, p. 267) which reached me yesterday, I have read an important note by W. H. Greene and S. C. Hooker, in which is proved the identity of the coloring matter of Bethabarra wood with lapachic acid. In ending their note the authors propose to study lapachone and suggest that certain reactions observed by them lead to the belief that this compound has not the constitution provisionally assigned by me in 1882.*

I must draw the attention of these two chemists to the fact that in my memoir, after having stated that the constitution of lapachone was perhaps the most difficult and important point to determine, I terminated by saying, that all my considerations had a very limited value and I dwelt on it but a moment, with the sole design of showing the importance and the range of the argument of which I had undertaken the study.

It is indeed true that since 1882 I have published nothing on lapachic acid. I have been occupied with other matters, it has been difficult for me to obtain first materials, and I did not desire to publish the results in parts, especially when I had reserved the right of continuing the research. However, that I have never abandoned the work is shown by the fact that in my research on Raoult's law, published conjointly with Nasini in 1886,† we proved that lapachone is not a polymeride of lapachone as I at first supposed, but that it corresponds to the simple formula $C^{15}H^{14}O^3$, and I said that while the polymeric quinones so far studied are brown substances, only slightly soluble and having fusing points much higher than the corresponding quinones, these great differences in external characters are not observed between lapachic acid and lapachone. Since that time, as I have besides announced a few months ago,‡ I have continued

* *Gazzetta Chimica*, **12**, 337. † *Ibid*, **16**, 262. ‡ *Ibid*, **19**, 3.

this research with greater industry, and by applying Raoult's method I have shown that the acetyl derivative of lapachic acid fusing at 131–132°, for which I had advanced a complex formula, corresponds rather to that of a diacetic derivative of lapachic acid or of lapachone or more probably another isomeride of this substance; and in a series of researches, that I may say are complete and which were in part made together with Sig. Minimi, I have entirely reconsidered the study of those derivatives of lapachic acid of whose constitution I entertained doubts, and in particular lapachone, the diacetyl derivative and the magnificent substance crystallizing in splendid bronze-red laminæ. Of lapachic acid and lapachone we have studied the oxime and hydrazin compounds, we have obtained the quinone corresponding to the diacetyl derivative, we have prepared and studied the triacetyl derivative, corresponding to the reduction derivative of lapachic acid, the compound of lapachic acid with thiophen has been prepared, and in this manner we have collected together a considerable number of facts which completely elucidate the constitution of lapachone and many other derivatives of lapachic acid.

I am sure that Messrs. Greene and Hooker will, after what I have exposed, allow us time to publish our labors and desist from the further investigation of lapachic acid derivatives, at least until after the publication of our researches.

ELECTROLYTIC SEPARATIONS.

By Edgar F. Smith and Lee K. Frankel.

[*Read at the Meeting of the Chemical Section, June 18, 1889.*]

I. SEPARATION OF CADMIUM FROM COPPER.

The results obtained in the electrolysis of cyanide solutions of mercury and copper, as well as the knowledge gained from our experiments in separating cadmium from zinc, induced us to try whether it would be possible to effect the evaporation of cadmium from copper in cyanide solution. The only electrolytic method pro-

posed for the separation of these metals is that recommended by Smith (*Am. Chem. Journal*, **2**, 42), in which solutions containing a definite amount of free nitric acid were employed. We experienced no difficulty in making a complete separation, after ascertaining the proper current strength. The conditions most favorable to the separation were essentially the same as those recorded in our former papers, viz: a dilution of 200 cc.; 5·5 grammes of potassium cyanide in each experiment, and a current generating ·28 cc. oxy-hydrogen gas per minute. Time sixteen to twenty hours. The results obtained were as follows:

Cadmium present.	*Cu present.*	*Cadmium found.*
	I.	
·2426 grs.	50 per cent.	·2420
	II.	
·2318	50 per cent.	·2331
	"	·2309
	"	·2315
	III.	
·1024	100 per cent.	·1028
	"	·1019
	"	·1020
	"	·1032
	"	·1033
	"	·1034
	"	·1014
	IV.	
·2046	100 per cent.	·2034

Copper was not found in any of the deposited cadmium, nor did we discover any of the latter metal in the filtrate containing the copper. The cadmium deposit invariably showed the gray color characteristic of it.

II. ACTION OF THE CURRENT UPON METALLIC SULPHOCYANIDES.

It is well known that in the electrolysis of the sulphate or nitrate of manganese the oxide of this metal separates upon the positive pole. We have found that if an excess of potassium sulphocyanide be present no such deposition occurs, but, on the contrary, the metal itself will separate as

a grayish white, compact deposit upon the negative pole or the vessel attached to it. The addition of a sulphocyanide to the manganese solution undergoing electrolysis, after the oxide has already separated, will cause the solution of the latter. The current necessary for the deposition of metallic manganese, under the conditions mentioned above, should be feeble. The metallic deposit is inclined to rapidly oxidize, and whether manganese can be successfully determined in a quanitative way after this manner will depend very much upon whether we can prevent its oxidation during the drying process.

Nickel, cobalt, iron and several other metals separate very rapidly from cold sulphocyanide solutions under the influence of a weak current.

CHEMICAL LABORATORY, UNIV. OF PA.,
PHILADELPHIA, June 18, 1889.

ON THE CONSTITUTION OF LAPACHIC ACID AND ITS DERIVATIVES.

BY SAMUEL C. HOOKER AND WM. H. GREENE.

[*Read at the Meeting of the Chemical Section, held Tuesday, May 21, 1889.*]

In 1857, Arnoudon* described, under the name taiguic acid, a yellow coloring matter existing in the Taigu wood of Paraguay; nine years later, Stein† described as greenhartin a similar matter which he had extracted from the greenheart of Surinam. In 1879, Paterno‡ proved the identity of these substances with the lapachic acid obtained by Siewert from the Lapacho tree of South America. Finally, we have recently found the same substance in a South African wood, the Bethabarra.§

Paterno,‖ in an admirable research published in the

* *Comptes rendus*, **41**, *1,152*.

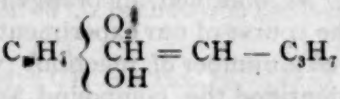
† *Jour. für prak. Chemie*, **99**.

‡ *Gaz. Chim. Ital.*, **9**, 506.

§ *American Chem. Journal*, **11**, 267.

‖ *Gaz. Chim. Ital.*, **12**, 337–392.

Gazzetta, 1882, has assigned to lapachic acid, with a very great degree of probability, the following constitutional formula:



Oxy-amylene-naphthaquinone.

The results from which this formula are mainly deduced are the following:

Lapachic acid gives a series of stable salts, but all experiments failed to reveal the true acid group, COOH.

On distillation with zinc dust, naphthalene and isobutylene were obtained.

On oxidation with nitric acid, phthalic acid was formed.

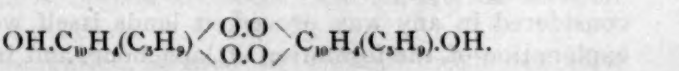
By reducing agents, a hydrolapachic acid was obtained, which rapidly absorbed oxygen, becoming reconverted into lapachic acid.

A monacetyl derivative was obtained.

Hydriodic acid and phosphorus gave a liquid hydrocarbon, which was taken to be amyl-naphthalene.

In the course of the study of this acid, Paterno prepared several compounds, which he was only able to explain satisfactorily by the assumption that two molecules of the acid had taken part in the formation of each of their molecules.

By the action of concentrated sulphuric acid on lapachic acid, a compound crystallizing in beautiful red needles is formed, which has precisely the same percentage composition as lapachic acid. This compound, which is known as lapachone, was assigned the following formula, by Paterno:



Lapachone is insoluble in alkaline carbonates; it is soluble in caustic alkalies only after boiling for some time. According to Paterno it separates from the alkaline solution on cooling and is almost completely precipitated unchanged on the addition of acids.

While recently engaged on the study of the coloring matter of Bethabarra wood, subsequently proved by us to be lapachic acid, we obtained an orange-red quinone-like substance. In the course of our experiments with this compound we observed a number of reactions which, when we had afterwards identified the compound as lapachone, did not agree with Paterno's view of its constitution.

We found that lapachone shows many of the characteristics of a chinone. It gives a white crystalline compound with acid sodic sulphite, which is reconverted by acids and alkalies into the original substance. It forms compounds with hydroxylamine and ammonia with great readiness, and gives the quinone color reaction of Bamberger.

These reactions are obviously not reconcilable with the formula given above and point to the probability that lapachone is $C_{15}H_{14}O_3$ and not $C_{30}H_{28}O_6$.

A determination of the molecular weight of lapachone, by Raoult's method, gave figures confirming this supposition, thus proving that only one molecule of lapachic acid is concerned in its formation, a result borne out by other facts.

Calculated for *Paterno's formula* $C_{30}H_{28}O_6$	*Calculated for* $C_{15}H_{14}O_3$	*Found.*
484	242	255

It remains, therefore, to explain how a substance having such strong acid tendencies as lapachic acid, dissolving with ease in alkaline carbonates, can be converted into an indifferent compound like lapachone, and yet retain the same percentage composition.

Although Paterno's formula of lapachic acid cannot be considered in any way proved, it lends itself well to the explanation of the formation of lapachone, and in this way considerable indirect proof is furnished of the probable correctness of Paterno's views in regard to lapachic acid.

It seems lawful to assume, that under the influence of strong mineral acids (concentrated nitric acid in the cold acts similarly to concentrated sulphuric acid as shown by Paterno) lapachic acid takes up a molecule of water,

giving rise to an intermediate compound, which is at once decomposed by the acid, again splitting off water, but in a different direction. This is shown in the following equation:

$$C_{10}H_4\begin{cases}O_2\\CH\\OH\end{cases} = CH.C_3H_7 + H_2O$$

Lapachic acid.

$$= C_{10}H_4\begin{cases}O_2\\CH_2\\OH\end{cases} - CH(OH).C_3H_7$$

Oxy-hydro-lapachic acid.

$$= C_{10}H_4\begin{cases}O_2\\CH_2\\O\end{cases}\!\!\diagdown\!\!\diagup CH.C_3H_7 + H_2O$$

Lapachone.

The fact that phthalic acid is produced by the oxidation of lapachic acid, would appear to furnish proof that all the side groups are situated in the same benzene nucleus, and consequently whether lapachic acid be a derivative of *a*- or *β*-napthaquinone the (OH) group must be in the ortho position to the amylene chain: this favors the probability of the occurrence of the above condensation.*

This view of the constitution of lapachone, *i.e.*, regarding it as a derivative of naphthofurfuran, agrees very thoroughly with all its properties and reactions so far observed. It has, moreover, received direct confirmation from the result of an experiment, which was made to obtain, if possible, corroboration of our views.

Paterno states, as already mentioned, that lapachone is insoluble in caustic alkalies in the cold, but dissolves on heating, and is, in part, deposited from the filtered solution unchanged as it cools.

This observation, seemed at variance with our idea of the constitution of lapachone, and we consequently carefully repeated Paterno's experiment. The insolubility of lapachone in alkaline carbonates and caustic alkalies in

* It is, of course, possible, though scarcely probable, that lapachic acid is derived from *β β*-naphthaquinone, in which case the relative positions of the amylene chain and the hydroxyl group would be the para.

the cold is readily explained by the constitution we have assigned to it, and its solubility on boiling is best accounted for by the supposition that the furfuran ring is split by the action of potash, that one molecule of water is taken up with the formation of a salt of the compound:

$$C_{10}H_4 \begin{cases} O_2 \\ CH_2.CH(OH).C_3H_7 \\ OH \end{cases}$$

Oxy-hydro-lapachic acid,

which we had previously supposed to exist as an intermediate product in the formation of lapachone. This explanation proved quite satisfactory, for on neutralizing with acetic acid, a red oil was obtained which, in the course of an hour or so, solidified to a yellow crystalline mass.

Analysis proved it to have the expected composition. The tendency of the new substance to pass into lapachone under the influence of dilute mineral acids is very great, and hence if dilute HCl acid be used for the precipitation, either a mixture of lapachone and the new compound, or lapachone only is obtained.

We have not yet succeeded in preparing the potassium salt of the new substance in a crystalline form, but as its barium salt, which crystallizes very readily in bright orange needles, closely resembles lapachone, it is not improbable that the potassium salt may have a similar appearance, which would account for Paterno's supposition that the crystals deposited on cooling and before the addition of hydrochloric acid were crystals of lapachone. It is right to add that the fusing point of these crystals was found by Paterno to be almost identical with that of lapachone.

The salts of the new compound as might be expected dissolve to the same intense red color as those of lapachic acid. It melts at 125°, and is very readily soluble in most ordinary solvents. It may be obtained in comparatively large crystals, by spontaneous evaporation of its solution in alcohol or acetic acid.

By the action of bromine on lapachic acid in acetic acid solution, Paterno obtained a compound which he regarded

as monobrom-lapachic acid and to which he assigned the formula

$$C_{10}H_4\begin{cases}O_2\\CH=CH.C_3H_7\\OBr\end{cases}$$

Considering the properties of this compound and the probable constitution of lapachic acid, its formation would seem to be better explained by the supposition that an addition product is first formed, and that this by splitting off hydrobromic acid, gives rise to the formation not of brom-lapachic acid but of brom-lapachone, thus:—

$$C_{10}H_4\begin{cases}O_2\\CH=CH.C_3H_7\\OH\end{cases}+Br_2$$

$$=C_{10}H_4\begin{cases}O_2\\CHBr-CHBr(C_3H_7)\\OH\end{cases}$$

$$=C_{10}H_4\begin{cases}O_2\\CHBr\\O\end{cases}\!\!>CH.C_3H_7$$

We are at present endeavoring to prove the truth of this supposition and have already observed some important facts tending to show the correctness of our views.

The formation of several of the other compounds obtained by Paterno, would appear to be better explained in a similar manner to the foregoing than by the formulæ he has assigned to them. We prefer, however, to leave the discussion of these until our work has progressed further. In the meantime, we wish to say that, although we are hopeful further experiments will justify our present conclusions, we do not regard them as of necessity final and have only been induced to make this preliminary communication to ensure to ourselves the undisturbed continuation of the work, which, owing to many causes, can not, unfortunately, proceed with as great rapidity as we could desire.

On KOBELLITE from OURAY, COL., and the CHEMICAL COMPOSITION of this SPECIES.

By Harry F. Keller.

[*Read at the Meeting of the Chemical Section, May 21, 1889.*]

The sulphobismutites and sulfostibnites of the south-western part of Colorado, have repeatedly formed the subject of mineralogical and chemical research. Genth, Koenig, Hillebrand, and others have proved the occurrence there of a number of species already known from other localities, and have also described several new compounds of this class under the names of schirmerite, alaskaite and beegerite.

In the following pages, I desire to give the description of a mineral, possessing the composition $2(Pb,Ag_2,Cu_2)S.(Bi,Sb)_2S_3$ and to show further that it is in all probability identical with the kobellite of Setterberg.

The material for this investigation was kindly supplied by my brother, Mr. Hermann A. Keller, of Pueblo, Col. It consisted of several beautiful specimens of an ore that had been taken from the Silver Bell mine at Ouray, Col., by Mr. Philip Decker.

I have not been able to obtain any further information concerning the occurrence of the mineral, but consider it highly probable that it is closely analogous to that of alaskaite described by Koenig.* Like this it is found associated with barite and chalcopyrite. *Physical properties:*—Massive; structure, finely granular, inclining to fibrous; lustre, silky metallic; color, bluish lead-gray; fracture, uneven; streak, iron-black. Apparent hardness, 2·5—3; sp. gr., 6·334.

Chemical deportment.—Upon heating, the mineral first decrepitates violently and then fuses. In the open tube, it gives off sulphurous acid and a sublimate of antimonious acid. Upon charcoal it yields a yellow incrustation, with a white non-volatile fringe and a metallic globule, which for

* *Amer. Philos. Soc.*, June, 1881.

the greater part is volatilized upon continued blowing. The residue gives the reactions of iron and copper in the salt of phosphorus bead, and a button of metallic silver on cupellation. A crimson coating is obtained with potassium iodide and sulphur on charcoal.

Hydrochloric acid decomposes the compound with evolution of hydrogen sulphide, especially upon heating; the gangue material and chalcopyrite are left undissolved, while the silver passes into solution, from which it can be precipitated as chloride by diluting with water.

Chlorine, as well as nitric acid, exerts a powerful action upon it.

As the quantitative separation and estimation of the constituents present some difficulties, I will briefly indicate the course of an analysis which was found to be best adapted to this end. A portion of the mineral was treated with nitric acid. When proper care is taken, the oxidation is completed in an hour's time. The excess of the acid was then removed upon the water bath and the residue boiled with a solution of pure carbonate of soda. This treatment was continued until all the sulphuric acid, excepting the small quantity in the barite of the gangue, had passed in solution. The undissolved oxides and carbonates of the metals were then filtered off. The filtrate showed a bluish color, and was found to contain small quantities of copper, antimony and bismuth. These were precipitated, by hydrogen sulphide, after acidifying with hydrochloric acid, and the sulphur then determined in the filtrate as barium sulphate. This was purified after ignition, by heating with hydrochloric acid, then dissolving it in concentrated sulphuric acid and reprecipitating it finally with water.

The separation of the metals was effected as follows: The mixture of the oxides, carbonates, etc., was treated with nitric and tartaric acids, whereby only the gangue material ($BaSO_4$) remained undissolved. After the small quantity of sulphides before mentioned had likewise been taken up in the solution, the silver was precipitated as chloride in the cold; potassium hydrate was then added to the filtrate in excess and hydrogen sulphide passed into it. The

precipitate, consisting of the sulphides of all the metals except antimony, was filtered off, and the antimony determined in the liquid according to Bunsen's method as pentasulphide. The conversion of the pentasulphide into tetroxide served as a check, but gave invariably a slightly lower percentage.

The metallic sulphides were again oxidized with nitric acid, the latter removed by evaporation with sulphuric acid and the remaining sulphates treated with dilute sulphuric acid (1 : 8) in the cold. In this manner the lead is separated from the other metals, but not completely, as the insoluble sulphate always retains small quantities of bismuth. It is therefore dissolved in warm potash solution, which leaves the oxide of bismuth with some lead, and these can then be separated readily by a renewed treatment with nitric and sulphuric acids.

In the solution containing the sulphates of copper, bismuth, iron and zinc, the two first mentioned were precipitated as sulphides with hydrogen sulphide, filtered off, converted into the nitrates and separated from each other with ammonia and ammonium carbonate. Zinc and iron were finally separated and determined by the usual methods.

In order to ascertain which of the metals enter into the composition of the mineral, one portion of the substance (Analysis II) was dissolved in hydrochloric acid and the residue remaining analyzed separately.

Although chlorine acts strongly upon the finely divided powder, I did not succeed in effecting a complete decomposition by its means. All the samples analyzed were taken from different pieces of the ore.

ANALYSES.

	I.	*II.*	*III.*	*IV.*	*V.*	*Mean.*
S	18·37	—	18·46	18·33	18·39	18·39
Bi	27·97	28·51	28·68	28·46	—	28·40
Sb	7·19	7·25	7·91	7·84	—	7·55
Pb	36·11	36·08	36·25	36·20	—	36·16
Ag	3·22	3·39	3·30	3·32	—	3·31
Cu	2·43	2·26	2·91	2·76	—	2·59
Fe	1·31	1·35	1·69	1·65	—	1·50
Zn	·50	·37	·41	·31	—	·39
$BaSO_4$, etc., .	·43	·65	·21	·49	—	·45
	97·53		99·82	99·36		98·74

In No. II the portion insoluble in hydrochloric acid was found to contain (after the chloride of silver had been removed by ammonia):

Fe, 1·09. Cu, 1·12. Zn, ·24.

It seems therefore safe to assume* that the iron and an equivalent quantity of copper are present as chalcopyrite, and the zinc as sphalerite.

Now deducting these, plus the gangue and the loss, the percentage composition calculated from the mean results is as follows:

		Atomic ratio.			
S	= 17·76	·5550		=	2·600
Bi	= 30·61	·1457	·2134	=	1·000
Sb	= 8·13	·0677			
Pb	= 38·95	·1881			
Ag	= 3·58	·0166	·2124	=	·995
Cu	= ·97	·0077			
	100·00				

and the formula is therefore: $2(Pb,Ag_2,Cu_2)S.(BiSb)_2S_3$. Since the atomic ratio of antimony† to bismuth is 1 : 2 the mineral may be considered as composed of one mol. of jamesonite with two mols. of cosalite.

The recent text-books of mineralogy do not assign this formula to any mineral, nevertheless such a one has been known for a long time.

As kobellite, Setterberg‡ in 1839 first described a mineral from the cobalt mines of Hvena, in Sweden, the composition§ of which he found to be:

S	= (18·61)
Bi	= 28·37
Sb	= 9·38
Pb	= 40·74
Fe	= 2·02
Cu	= ·88
	100·00

* Chalcopyrite, when finely divided, is slightly acted upon by HCl.

† I have reason to believe that the antimony determinations I and II are a little too low.

‡ *Pogg. Ann.*, **55**, 536.

§ Recalculated with present atomic weights (Rammelsberg, *Mineraich.*, p. 100).

Deducting from this the copper with the equivalent quantities of iron and sulphur, the atomic ratios are as follows:

S	= ·5506		= 2·581
Bi	= ·1351	·2133	= 1·000
Sb	= ·0782		
Pb	= ·1966	·2187	= 1·025
Fe	= ·0221		

that is, they are identical with those calculated from my analyses.

Setterberg states distinctly that the iron of his mineral was dissolved in hydrochloric acid, and must therefore be considered as belonging to it; another slight difference in the composition of the minerals from the two localities is the replacement of about one-twelfth of the lead by silver in that from Ouray.

In 1862, Rammelsberg published an analysis of some material from the Hvena mine; he found:

S	= 18·22
Bi	= 18·60
Sb	= 9·46
As	= 2·56
Pb	= 44·25
Fe	= 3·81
Cu	= 1·27
Co	= ·68
	98·85

After deducting 5·61 per cent. of (FeCo)AsS and 3·67 per cent. of $CuFeS_2$, he arrives at the formula

$$Pb_3BiSbS_6.$$

In his *Mineralchemie* (p. 100), he gives an analysis of so-called kobellite from another locality (the name of which is not mentioned), and from this deduces the same formula.

He does not prove, however, that the analysis by Setterberg is incorrect, and it is more than likely that the material examined by him consisted of a mineral different from Setterberg's.

There are numerous instances of the occurrence of two different sulpho-salts of similar appearance in the same vein, and even upon the same piece.

The re-investigation of alaskaite by Koenig* was caused by it having been mistaken for cosalite from the same mine.

The specific gravity determinations also show a slight discrepancy; Setterberg found 6·29 — 6·32, while Rammelsberg's determination gave 6·145. That of the Ouray occurrence is 6·334.

In view of all these facts, I feel myself justified in retaining the name of kobellite for the mineral of the formula:

$$2(Pb,Ag_2,Cu_2,Fe)S.(Bi_{(3)}Sb_{(3)})S_3,$$

and would suggest that another name be given to that to which this name has hitherto been applied, namely,

$$Pb_3SbBiS_6.$$

In concluding, I desire to propose the name of lillianite for a mineral from the Lillian mine in Leadville, Col., described several years ago jointly by my brother and myself as a variety of kobellite. It possesses the composition $3(PbAg_2)S.Bi_2S_3$, and represents the bismuth mineral corresponding to boulangerite.

II.—ANALYSIS OF MEGABASITE FROM BONITA MOUNTAIN, NEAR SILVERTON, COL.

More than three years ago I received from Colorado, among other specimens, one which was labelled "gœthite." Some qualitative tests that were then performed upon it proved that it consists essentially of tungstic acid and manganous oxide. The occurrence has become quite well known since, but, as far as I am aware, no quantitative analysis of the material has been published. I may therefore be permitted to put the following on record:

Sp. Gr. = 6·780

WO_3	=	74·24
MnO	=	21·09
FeO	=	2·06
CuO	=	·11
MgO	=	trace
SiO_2	=	2·13
		99·63

CHEMICAL LABORATORY, UNIV. OF PA.,
PHILADELPHIA, May 21, 1889.

* *Proc. Amer. Philos. Soc.*, 1885, 211.

THE ELECTROLYTIC SEPARATION OF CADMIUM FROM ZINC.

BY EDGAR F. SMITH AND LEE K. FRANKEL.

[*Read at the Meeting of the Chemical Section, May 21, 1889.*]

The separation of these metals has been effected by Yver (*Bull. Soc. Chim. de Paris*, **34**, 18), who employed the acetates for this purpose.

Eliasberg (*Zeitschrift für Analyt. Chemie*, **24**, 548) and Smith and Knerr (*Am. Chem. Journal*, **8**, 210) confirmed this observation, at the same time emphasizing the fact that the current should be carefully regulated, otherwise unsatisfactory results would be obtained. A solution containing cadmium and zinc as tartrates, together with free tartaric acid, will also yield all its cadmium to a current generating 0·4—0·5 cc. oxy-hydrogen gas per minute (*Am. Chem. Journal*, **8**, 210). We have no record of other salts of these metals having been used for their electrolytic separation, and therefore have taken occasion to learn what the result might be with solutions of the double cyanides, such as we employed in separating mercury and copper (JOURNAL FRANKLIN INSTITUTE, **127**, 469, and *Am. Chem. Journal*, **11**, 264).

Beilstein and Jawein (*Ber. d. d. chem. Gesellschaft*, **12**, 446, 762) have shown that both cadmium and zinc can be completely precipitated from a cyanide solution, but have not given the current strength employed by them in their experiments, nor did they attempt the separation of these metals from each other.

As our experience with mercury and copper clearly indicates, it is frequently possible, by close attention to the current, to effect electrolytic separations, which ordinarily seem impossible. With this fact clearly before us, our first work with the metals now under consideration was to ascertain how feeble a current would suffice for the complete deposition of each metal, when alone in a cyanide solution, in the presence of an excess of an alkaline cyanide. We very soon discovered that the cadmium separated readily

and with a much weaker current than was necessary for the deposition of the zinc. The latter will, however, separate from a cyanide solution, even under the influence of a feeble current, but not until the excess of cyanide has been completely decomposed. With the quantity of cyanide used by us, and with a current of the strength indicated below, this complete decomposition of the alkaline cyanide is not likely to occur in a shorter period than forty-eight hours. Hence, it follows, that as the quantity of cadmium used in our experiments is entirely precipitated in a little more than eighteen hours, the complete separation of cadmium from zinc is thoroughly feasible by this method.

All our experiments were conducted in the cold, and care was taken in each case to examine the deposited metal for zinc, and the residual solution for cadmium. The conditions under which our work was carried on and the results obtained are these:

Metallic Cadmium in Grammes.	Cadmium found.	Metallic Zinc present.	Difference in per cent. of Cadmium.	KCN in Grammes.	Total Dilution.	Current in cc. of O–H Gas.	Time.
			Per Cent.				
·1817	·1813	. . .	— ·22				
	·1818	. . .	+ ·05				
	·1815	. . .	— ·11				
	·1822	. . .	+ ·22				
	·1812	·2000	— ·27				
	·1818	·2000	+ ·05				
	·1828	·2000	+ ·60				
·2426	·2422	. . .	— ·16				
	·2432	. . .	+ ·24				
	·2426	. . .	. . .				
	·2420	·2000	— ·24				
	·2435	·2000	+ ·30				
	·2429	·2000	+ ·12				
	·2426	·2000	. . .				
	·2433	·2000	+ ·08				
	·2434	·2000	+ ·32				
				4·5 grammes in each separation.	200 cc.	0·3 cc. in each experiment.	18–23 hours.

The cadmium deposit was light gray in color and crystalline in structure. It was washed with hot water and dried upon a warm iron plate.

CHEMICAL LABORATORY OF THE UNIV. OF PA.,
PHILADELPHIA, May 21, 1889.

DERIVATIVES OBTAINED FROM MONOCHLORDINITROPHENOL AND BASES OF THE AROMATIC SERIES.

By Edgar F. Smith.

[*Read at the Stated Meeting of the Chemical Section, May 21, 1889.*]

It is well known that picric acid combines readily with bases and the higher hydrocarbons of the aromatic series to form well crystallized and stable compounds. It has, however, not been observed that phenols, containing less than three nitro-groups, together with other negative groups or elements, possessed this acidic property of picric acid. Several years ago (*Am. Chem. Journal*, **1**, 180) I discovered that when monochlordinitrophenol (1 : 2 : 4 : 6) and aniline were brought together there resulted a rather stable derivative, which did not decompose in aqueous solution until after prolonged boiling. Recently I have obtained derivatives with this same chlordinitrophenol and the bases and hydrocarbon mentioned below.

The phenol itself forms yellow-colored needles, melting at 80° C. Its *α-naphthylamine* derivative consists of brownish-yellow crystalline tufts, composed of velvety needles, melting at 131° C., and solidifying at 110° C. It was obtained by dissolving equal quantities of the phenol and *α*-naphthylamine in hot alcohol; on cooling, the new compound separated quite rapidly. It dissolves in warm water. The *o-toluidine* derivative, obtained by heating together equivalent quantities of the phenol and toluidine, consists of golden yellow plates, soluble in hot alcohol. It melts at 140° C., and solidifies at 115° C.

The *p-toluidine* compound separated from its alcoholic solution in reddish-yellow needles, was quite soluble in water, and melted at 157° C. With *urea* the phenol does combine, but the union is evidently unstable, since by exposure to the air a gradual change in color was perceptible. The *carbazol* compound consists of intensely red colored needles, melting at 121° C. It dissolves quite readily in alcohol.

With *p-nitraniline* long needles were obtained. Their color resembled that of chromic acid. It was rather difficult to obtain them pure. The *anthracene* derivative forms plates with an intense red color. The union is not stable, and exposure to the air causes a gradual decomposition. The *morphine* compound is made up of bundles of needles, having a deep vermilion color. It dissolves in alcohol, and melts at 97° C. The combination with *propylamine* is a yellow, crystalline solid; that with *strychnine* consists of yellow nodular crystals, melting at 212° C.

The determination of the carbon and hydrogen in the aniline compound, and that of the nitrogen in the *a*-napthylamine and *o*-toluidine derivatives, show that all the products described above are very probably combinations of a molecule of the chlordinitrophenol, with a like amount of the basic body.

I have further observed that dichlormononitrophenol, obtained in the nitration of dichlorsalicylic acid (*Am. Chem. Journal*, **8**, 98), does not unite with aniline, so that it would seem that the acidic character of the phenol reached its limit with the dinitro-product; and that union with bases such as those given above, is not possible when but one NO_2 group is present.

The facts here communicated are to be regarded as preliminary to an investigation now going on, but which must shortly be suspended for some months.

CHEMICAL LABORATORY OF UNIV. OF PA.,
PHILADELPHIA, May 21, 1889.

CORRESPONDENCE.

WASHINGTON, D. C., June 20, 1889.

To the Committee on Publications.

GENTLEMEN:—The following graphic construction for determining the electrical resistance of divided circuits has, I believe, never been published. It is probably of no practical importance, but may however be of sufficient interest to be placed on record.

Let it be required to determine the electrical resistance between the points *M* and *N* of *Fig. 1*, connected by two conductors; one of three ohms and the other of six ohms.

Through two arbitrary points, *A* and *B*, of an indefinite straight line, draw the two ordinates *A6*, *B3* proportional to the given resistances. Through *O*, the intersection of the diagonals *A3*, *B6*, draw the ordinate *OK*, the length of which gives the required resistance, two ohms.

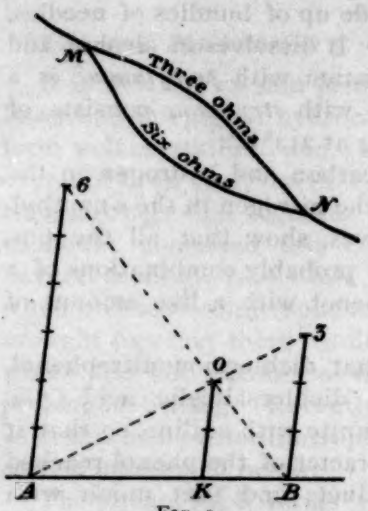


FIG 1.

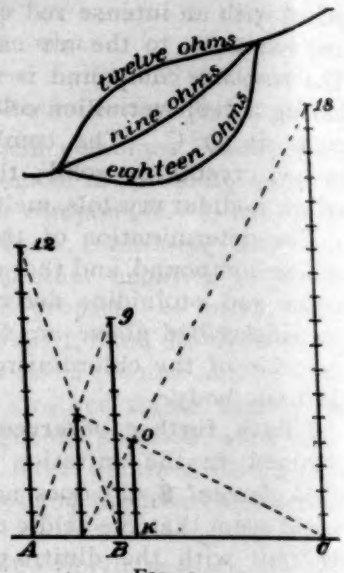


FIG. 2.

Fig. 2 shows the same construction applied to a divided circuit of three branches of twelve ohms, nine ohms and eighteen ohms.

The branches twelve and nine have a combined resistance of five ohms, which with the parallel branch of eighteen ohms give four ohms.

The same construction may evidently be applied to any number of branches.

J. B.

BOOK NOTICES.

THE CHRONICLE FIRE TABLES FOR 1889. A record of the fire losses in the United States by risks, States and causes during 1888, with exhibits of the monthly, annual and aggregate fire losses in the United States during fourteen years (1875–1888), and much other interesting and valuable information for fire underwriters. The Chronicle Company, limited, New York. Price, $5.

This excellent statistical work, now in the fifth year of its present form (though previously a smaller volume was published, with data not so full, dating back to 1875), is becoming annually more and more important; there is not a similar work in the world which can equal it. The volume is of royal octavo, and filled with the fullest data pertaining to the subjects set forth in its title. There is a general review of the fires occurring in the United

States during 1888, with discussions and comparisons of their amounts of losses and causes. Next comes the principal tabular statement, occupying eighteen pages, wherein, following nearly the classification of the Tenth Census of the United States, the number of fires during 1888 in each classification is given, together with the property and insurance loss, and causes of the fires reported.

One valuable addition hereto is a list of fires and their losses happening in warehouses of different descriptions, comprising thirty-nine kinds of storage. The modes used to insure accuracy are known to us, and are about as perfect as human ingenuity can devise. Absolute correctness in such data is not possible, but here is a close approximation. The fires and their losses are afterward given in same classes by States and Territories, occupying eighty-six pages. Another table exhibits the fires by causes, with number, losses on original risks, insurance thereon, losses on exposures and their insurances, besides the character of risks where fire originated. Nothing could be better devised than this compendium, in connection with the other data given, to facilitate study of this subject.

There are extensive tabulations, showing the number and kinds of risks burned in the United States for fourteen years (1875–1888), the monthly losses by fire in States and Territories during 1888 and for the thirteen previous years; also, an appendix, giving the number of lives lost by fires during the past year, reports of tornadoes accompanied by fires, besides much other statistical information respecting fires due to special causes, such as electricity, petroleum, etc. There are five charts, showing by various degrees of shading the distribution of incendiarism in the United States, and several diagrams exhibiting the monthly curves of incendiary fires and their failures during the year. An attractive diagram in blue, at the front, shows, by different divisions and shadings, where and to what degree fires due to defective flues—one chief cause—prevailed. We think that all business men, insurance companies, attorneys, students and all public institutions and libraries should possess these valuable fire tables and the four volumes which precede them. To the student of social economy they are simply invaluable.

N.

Curve Pictures of London for the Social Reformer. By Alex. B. MacDowall, M.A. London: Sampson Low & Co. 12mo. 1888.

The object of this volume of fifty pages is to give graphic views by diagrams, each having a page of explanation, of important facts relating to London and phases of its life in different times and conditions. These diagrams show in various percentages, etc., the population of the city and its density, birth-, marriage- and death-rates, early marriages, deaths by disease (four diagrams), suicides, drunkenness, licensed houses, apprehensions, felonies and property, pauperism (four diagrams), education, illiteracy, prices of commodities and prices of meat. The increase or decrease of the subject treated is also clearly shown.

The population is compared with that of Scotland, Paris and New York; its vast increase has been from 958,863, in 1801, to 3,800,000, in 1881. The density of population per acre varies much, and is delineated by districts

and sub-districts. Marriage is shown to fluctuate with trade, and exhibits a general decline; early marriages, however, are increasing, thus tending to increase poverty. The violence of the principal diseases is shown at different times, and by number of deaths per 1,000 of population. The death ratio of the city has fallen with improved conditions of life. This enumeration will suffice to show the student of economic science, and others, that here is a considerable field for research. This condensed work holds information which could fill a volume five times its size. The book is well worthy of careful study. S. H. N.

NOTES AND COMMENTS.

MECHANICS.

PRODUCTS OF THE SIMONDS ROLLING MACHINE. By S. L. Wiegand. (Abstract of remarks made at the Stated Meeting, held Wednesday, June 19, 1889.)—At the meeting of the INSTITUTE, held one year ago, Mr. George F. Simonds, of Fitchburg, Mass., exhibited by a model and explained by diagrams, a newly-invented machine for rolling metals into forms which not only performed the work of the smith forge better than smiths had ever done it, but also produced many articles in metal completely finished without either cutting, filing or grinding them. (His paper was published in the JOURNAL, July, 1888.)

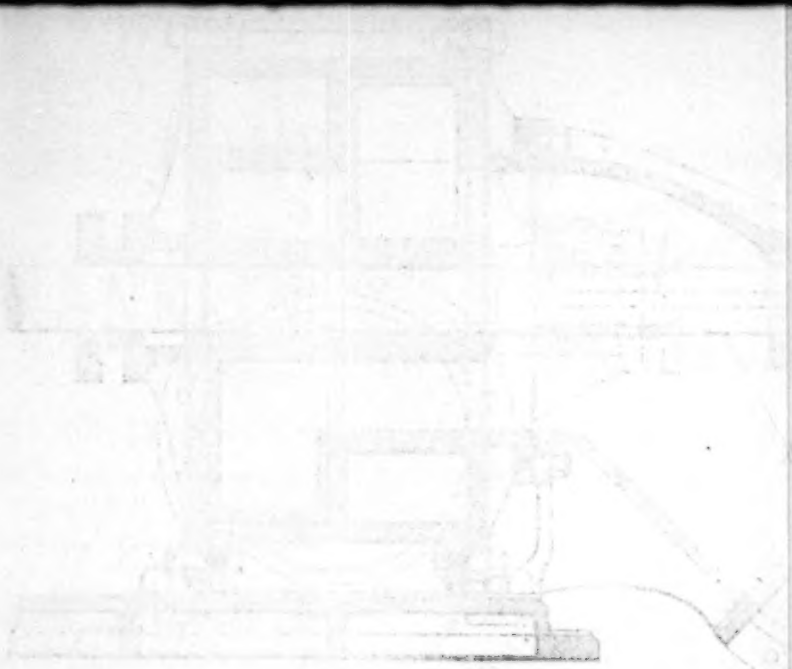
This invention was referred to the Committee on Science and the Arts, and, after careful examination, was pronounced so important and useful that the Elliott Cresson Medal was awarded to him for it, and their report was published in full in the JOURNAL for November, 1888.

Conspicuous among the products shown were very accurately formed, hardened and polished cast-steel balls for use in avoiding friction between the parts of machines.

Many persons observing them and their intended application, expressed doubt of their utility and durability.

The diagram (on the screen) shows them in several applications in which they have been tested severally with the best results, as to easy running of the machines and their apparently excellent durability.

Another slide shows the improved form of machine for making such balls in which the balls are used in all the high-speeded bearings.

Incidentally there occur in this machine two worm-wheels and endless screws, replacing a train of spur-wheels and pinions employed in the earlier machine, and which show a marked and most unexpected durability at high speed under great strain and indicate that under high velocities and with proper lubrication, such gearing moves with less friction, proportionally, than in slower moving machines—a fact of considerable interest to machine constructors, encouraging them to avoid long trains of reducing mechanism to convert the high velocities of electric motors into the slower speeds demanded by many operations in the arts.

A number of additional specimens are here shown, an inspection of which will tell more to the eye of a mechanic than anything that can be said.